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What Characterizes a System Builder? The Role of Local Energy Companies in Energy System Transformation

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Abstract: This article focuses on the development of sustainable energy systems in the Swedish local context and, specifically, on the actors that have proved to be crucial for such transitions: municipally owned energy companies. With the theoretical lens inspired by LTS's (large technical systems), the concept of the system builder was analyzed for the purpose of further understanding what characterizes the system builder—a frequently used but seldom problematized concept. This paper originates from earlier studies based on interviews and official documents. In this article, the municipal energy company and its role throughout the processes is used to illustrate how system builders act and can influence the development of energy systems. Three examples are used to illustrate how system building has been enabled through controlling the objectives and visions of the local energy planning, through enrolling the city council, and finally through recognizing the opportunity to expand the market through the coordination of systems. In this case, the system builder was characterized by the ability to act as a collective, as one unit, despite the multitude of individuals representing the organization, by the use of skills and knowledge in different policy processes, and by the ability to recognize opportunities in combining different sociotechnical systems. The need for system builders to act on expanding as well as stagnating systems is also shown.

Keywords: system builder; energy system; municipality; energy company; policy processes

1. Introduction

Local-level change is often seen as crucial to developing sustainable energy systems. Local authorities are often considered leading actors in the local adaptation and implementation of ambitious national and international energy objectives [1,2]. In the energy sector in Sweden, municipalities have traditionally played key roles as suppliers of gas, electricity, and district heating to the public sector and end-use consumers (*i.e.* business/industry and household consumers). These systems have usually been organized in the form of municipally owned energy companies. These companies own power plants and distribution networks in the municipalities, and in that way have become key actors in the energy area [3–5].

Swedish energy policy, as in many other countries [6], has traditionally mainly constituted an energy supply policy. Kaijser *et al.* (1988) claim that Swedish energy policy objectives of the 1970s mark a shift in the energy sector from a supply doctrine to a doctrine of greater efficiency. Energy use efficiency was to be improved partly through the efficient use of energy flows, partly by using renewable energy sources, and partly by more efficient end use [7]. This new emphasis on energy efficiency brought with it new important actors in municipal energy policy work. Energy advisors employed by municipalities, housing companies, local environmental authorities, *etc.* suddenly

became much more visible in local energy systems [3]. Always present on the local scene are local politicians who have authority over spatial planning, energy planning, and local environmental and energy goals. Among other tasks, they set priorities through the annual budget, represent the owners (*i.e.* the citizens) in relation to municipal energy companies, and serve as members of the local energy company boards. Several studies have noted that municipal energy companies occupy strong positions in municipalities and often act as system builders [3–5,8].

Here, we discuss these municipal energy companies and their system builder role. A system builder is an actor driving the development and construction of a system [9]. Although the system builder concept is well established and frequently used, for example, when analyzing actor roles in technological transformation, few in-depth studies examine system builders, and those that do often simply define actors *as* system builders. The present article accordingly concentrates on deepening our characterization of system builders in order to develop the system builder concept. What resources do system builders need? To answer this question, we consider earlier studies of a Swedish municipality, a municipality that we have previously studied from a historical perspective, that owns an energy company to understand how and why local energy systems have developed as they have. In this article, we re-analyze these studies, focusing on the energy company's role over time and its interests, resources, and ability to influence local policy processes over the years.

The article is organized as follows. After this introduction, the theoretical concepts of sociotechnical systems and system builders are explained. The method of the study is then described and background information on the studied municipality, as well as the significance of municipally owned companies, is presented. This is followed by the results of the study, which analyzes three examples of system building. The results are then discussed and the concluding remarks finally presented.

Sociotechnical Systems and the Role of System Builders

We analyze one municipal energy company that has developed sustainable sociotechnical systems in a local context. In particular, we analyze this development by citing three examples illustrating how municipal companies can act as system builders empowered and willing to develop a system in a certain direction. We define an actor as comprising one or more individuals connected to a particular organization. This means that an organization can function as a resource for an individual who can serve as its representative. In our material, though the informants often refer to organizations as actors, we maintain that it is always individuals who act. An organization consists of individuals with more or less common goals and guidelines.

In this section, we explore the theoretical concept of system builders by studying how previous studies have considered and defined this role. First, however, we define the concept of the sociotechnical system.

As sociotechnical systems, energy systems comprise technical components, individual actors and organizations, legal frameworks, and institutional and political structures. A sociotechnical system is interwoven with the societal context and cultural values in which it operates as well as its specialized professional knowhow. The term *sociotechnical* signals that we are including social and human as well as technical components in the system, considering them all interdependent. From this perspective, sociotechnical systems are regarded as seamless webs of tightly interconnected components: Changes made to one part of such a system must be adapted to the system's other parts to obtain a working whole. Accordingly, governing the innovations and policies that affect technology requires both social and technical knowledge of the involved systems [9–12].

The development of sociotechnical systems has often been analyzed through the lens of the large technical system (LTS) framework. This framework, developed by Thomas Hughes [9], has mainly been used to analyze the establishment of systems, which is probably why it has emphasized the constant growth of systems. Hughes describes how a system develops through a series of phases. In the *invention phase*, a new technological system emerges around radical inventions. In the *expansion*

phase, the system grows and adapts in competition with rival systems and, to survive, it must adapt to economic, political, and social conditions. Another phase, the *technological transfer* phase, occurs whenever a system is exported to a different environment, for example, a new city or country. When a system has become established and mature, it acquires *momentum*, giving it an appearance of autonomy from its environment, making it difficult to change the system's direction. Some later researchers [4,13] have added the *stagnation* phase to Hughes' earlier phases to emphasize what happens when a system stops expanding.

The identity of the system builder can, according to Hughes, vary between system development phases because different phases often require different skills. Initially, the inventor is important in solving critical problems occurring in relation to the economic, political, and social characteristics to which the invention must adapt in order to survive. In expansionary phases, managers/entrepreneurs are important in solving problems. Funders or politicians can also be system builders in certain phases [9]. System builders are less evident in earlier studies of the stagnation phase, which assign no specific actor that role.

According to Hughes, system builders are generally the actors who drive system development and construction. They also operate the system and must resolve the critical problems that occur when one part of the system does not develop in step with the rest, threatening the system's continued expansion. System builders are the actors driving the process and thus the management of sociotechnical system building and maintenance. Their participation is crucial to system development.

In various fields, it is common to study actions in relation to agents. For example, in policy research, two distinct types of actors are policy entrepreneurs and policy brokers, both said to have considerable potential impact on policy outcomes. Policy entrepreneurs act more in self-interest, while policy brokers seek stability and practical policy outputs [14]. Policy brokers mediate between interests [15], while policy entrepreneurs promote their own interests by trying to convince others to support them [16]. Earlier research into system builders reflects somewhat similar characterizations. One distinct difference is that, as explained above, different actors play the system builder role in different phases of a system's development. In that sense, there is no single heroic actor destined to build a whole system.

How LTS's develop can be compared to ecosystems and ideas about how an ecosystem develops. An ecosystem can be defined as "a network of interconnected organizations, organized around a focal firm or a platform and incorporating both production and use side participants" [17]. Symbiosis between involved actors drives interdependency between actors, *i.e.*, that each actor is complementary, and co-evolution, *i.e.* that the participants develop in step with each other [17]. The organizations are more in focus in ecosystems than in LTS's.

Summerton [8] studied the social shaping of a district heating system in a Swedish municipality and has elaborated on the definition of system builders, summarizing four important tasks, or challenges, facing these actors. First, a system builder must *enroll other actors in order to reach a shared purpose*—that is, a system builder needs support from various actors who will jointly support system development. Second, a system builder must *expand the market* while defending it from competitors. Competition between actors and technologies may appear throughout the process of technological system development, meaning that the system builder must continuously defend and try to expand the market. In this sense, the system builder resembles the policy entrepreneur, but the system builder defends the system rather than his or her own self-interest. Third, a system builder must *handle conflicts and critical points* that appear during the development processes. Finally, a system builder must *coordinate the processes* connected to system development, for example, so that political decisions are coordinated with the decisions made by the system builder and other enrolled actors [8].

The system builder can be compared with what Miller *et al.* [18] has defined as a system integrator. A system integrator is the intermediary between clients, regulators, and professional bodies. Winch [19] thinks that a system integrator has at least three functions general for complex systems:

- the skills to integrate interdependent components into a coherent whole;

- detailed knowledge of client requirements; and
- knowledge of the rules and regulations governing the industry.

Compared to Summerton's stated challenges, knowledge and skills are emphasized more in this context.

In the entrepreneurship literature organizations are important, but here the individual is also in focus. Entrepreneurship studies reasons why individual starts new business and why some individuals recognize an opportunity while others do not. The decision, e.g., to make an investment is described as a process where an individual identifies an opportunity and evaluates the value of exploiting it as sufficient [20,21]. Why some individuals recognize opportunities is explained by characteristics related to the entrepreneur, such as prior knowledge, experience and skills, psychological characteristics, networks, and interests [20]. The entrepreneur's goals are also important, and in recent literature social entrepreneurs and their desire to contribute to social and environmental change have also been highlighted [22]. All of these reasons for why an entrepreneur acts (or does not) are also important for understanding the characterization of a system builder.

The concept of the system builder has also been used in some earlier studies of the development of large technological systems [23–26] and energy systems in the local context [4,8,27]. To summarize the role of the system builder according to these studies, the system builder can be understood as a driving actor with a clear vision of the interconnectedness of the whole system and of what is required to achieve the system's goal. These actors are formally autonomous, making their own decisions and acting according to their own criteria. System builders are central to making sense of the system development process. Their actions and capacity to unite varied interests are crucial to making changes to the system. Overall, system builders strive to control and expand the development of the system. However, in these studies, the system builder concept is applied without reflection and lacks elaboration.

Thus, the present paper examines the role of system builders in order to develop and explore their characterization. By emphasizing the theoretical concept of system builders and illustrating their actions with three examples of a local energy company, we seek a better understanding of this role and of how the concept can be developed. In the following, we will examine how system builders must *enroll actors, expand the market, handle conflicts, and coordinate processes,* together with the role of *skills, experience, knowledge, networks* and *interests.* However, methods and materials will be presented first.

2. Materials and Methods

This analysis is the outgrowth of in-depth studies of the development of energy systems in one municipality—Linköping—in Sweden. The case of Linköping can be seen as a critical case, *i.e.* if it holds for this case, it will hold for many [28]. Flyvbjerg [29] discusses that it is more difficult to identify a critical case than to answer what constitutes such a case. In our case, the choice depended on the existence of a system builder, which in Linköping had long been the municipal energy company. Our case study is qualitative and the case is not expected to be representative of how *all* energy systems develop locally; nevertheless, certain analytical generalizations regarding system builders are generated from the study [29,30].

In two research projects, we studied how and why the local energy system developed as it did from 1976 to 2005. The first project followed how municipal energy policy developed and in what arenas decisions were made that influenced local energy policy. The second project sought to understand why biogas was introduced into Linköping and by what actors.

Both projects involved systematic archival studies of official documents, including primary sources such as investigations, minutes, and notes. To complement the archival studies, we interviewed local actors from the public sector (e.g., local politicians, municipal officials, and local energy company representatives) as well as representatives of private firms and other related organizational bodies. The purpose was to follow the policy process from the emergence of an issue until the final decision and implementation.

Altogether, semi-structured interviews were held with 44 officials and politicians, who were interviewed one to three times depending on how long they were active. Those who had been key persons for several decades were interviewed several times, focusing on different aspects (such as planning, waste incineration, and biogas) of the energy system. See Appendix 1 for an overview of the interviewees. The interviews are referred to in the following text by using "Interview" and a number to indicate the exact interview (see Appendix 1).

The respondents were identified both by the documents and by the fieldwork method of snowball sampling, *i.e.* respondent recommended other possible respondents who would be relevant to interview.

Both projects used similar interview guides (see Appendix 2) covering: respondent background and role in the process; how respondents perceived the ongoing processes; when and why certain issues were treated in each process; the influence of various actors at different stages; and specific questions arising in relation to each observed process. The sequence of questions and the attention paid to various topics depended on the specific informant. Such flexibility also allowed other relevant topics to emerge [31]. All interviews were recorded and transcribed. For this paper, we re-analyzed the interviews. In practice, this means that we read through all the interviews to get an overview of the content. In the next step, we searched through the documents using keywords to find passages where enrollment of actors, networking, conflicts, and the exclusion and inclusion of both issues and actors were discussed. The passages were then condensed into shorter statements that were sorted into empirically and theoretically derived themes [31].

The interviews provided us with a picture of how the interview framed "system building" and what characterizes actors that drive different processes. Following Czarniawska [32], interviews are not seen as a window of social reality but are a part or a sample of that reality. The interviews give important insights into how the actors perceived and interpreted a certain phenomenon such as a meeting, a policy process, or a decision [31]. An informant's statement can, strictly speaking, only represent that person. When we analyzed the material, however, we looked for similarities and patterns between different interviews. The sample of interviewees are, as described above, qualitative and not quantitative, which makes it uninteresting to present, e.g., how many persons made a certain statement [32,33]. The interviewees' perceptions were compared with other interviewees and with the documents. The validity of this study is in this way supported by data triangulation, *i.e.* the use of multiple data sources and respondents [34].

Yin describes four criteria from which to discuss quality: construct validity, external validity, internal validity, and reliability [35]. Construct validity testing confirms that research data collection is based on a logical process that maintains consistency from the research question to conclusions. In our case, we used multiple sources of evidence. The interview data was both taped and transcribed in real time, and we let all our informants review drafts of our reports. External validity ensures that the findings are applicable outside the confines of the selected case study. This is mainly tested through patterns identified across the examples and in relation to earlier research. The internal validity evaluates the evidence for pattern matching and establishing causality. This is mainly done through analytical generalization where the findings are generalized into the broader theory on system builders. The test for reliability verifies that the research procedures and findings can be replicated by other parties. These data collection procedures were followed, and a consistent set of questions were used in each interview

Background: The Linköping Case

Linköping, a municipality in Southeast Sweden, is the fifth largest municipality in Sweden with approximately 150,000 inhabitants. Linköping owns 100% of the energy company Tekniska Verken i Linköping AB (TVAB), which provides energy, water, sewage disposal, refuse collection and disposal, waste treatment, broadband Internet, and other services. TVAB has both private and public customers,

mainly in the Linköping municipality area but, since energy market deregulation, elsewhere in Sweden as well.

TVAB is subject to ordinary legislation governing private limited companies. It has a board of directors, appointed by the municipality proportional to the number of members elected from various political parties, responsible for day-to-day operations. As the municipal council determines the purpose and objectives of its companies, TVAB requires formal municipal council endorsement before deciding, for example, on large investments, rate changes, and major policy issues. Once the directors assume their board seats, they no longer represent their political parties but rather the company and must therefore act in the company's best interests—a fact that often results in conflicts of interest and values [3,36,37].

A municipal energy company, whose employees often act as system builders, is an organization that must act in several arenas. Municipally owned companies have been described as "rare bird[s] in the municipal nest" [38], even though these companies represent much of the municipal economy in terms of both scale (25%) and capital (approximately 45%) [27]. Municipally owned companies are hybrid organizations, neither purely public administration nor business entities, as they combine features of both organizational forms and exist at the intersection of the market and public sectors. These companies fall between two sets of institutional rules, ending up in a dilemma in which they must simultaneously meet requirements based on both political and market logics [39–41]. The energy system is subject to key democratic principles: For example, issues should be debated, proposals sent for consultation, and the process open to the public. Simultaneously, the energy system should be treated as a limited company operating in a competitive market in which quick decisions are often required and an open and transparent process can create problems for the company's business relationships and competition concerns. To summarize, municipal companies differ from other kinds of organizations and are important actors in many arenas. We have chosen a case where a municipal energy company has acted as a system builder in the local energy system. There is also of course a wide range of other actors that can act as system builders in the local energy system such as local authorities, private business, interest organizations, and grassroots initiatives.

Local energy companies' importance for energy system development and their powerful positions in municipalities were treated in our earlier studies referred to above. Energy companies have been called system builders, but what characterizes these system builders has not yet been the focus of analysis. This article seeks to fill this gap and help characterize system builders in general.

3. Results

Below we will discuss how Linköping municipality's local energy company, TVAB, has acted through its employees and board members as a system builder by using available local resources and exploiting its dual role both as part of the municipal organization and as a market player. We will cite three examples of processes in which TVAB acted as a system builder and where different tasks or challenges had to be overcome to maintain or expand the system. In the example of energy planning, the system builder needed to coordinate processes and make use of its resources. In the example that concerns the interaction with its owner (the municipality), the system builder again needs to coordinate processes and also handle conflicts. In the example with initiating a new system for biogas production, the challenges are related to expanding the market and enrolling actors.

3.1. Energy Planning: A Way to Coordinate Processes

The Swedish national government approved a law on municipal energy planning in 1977 in response to the emerging energy crisis of the 1970s. Through this law, national government sought to use municipalities to achieve its energy policy ends, inducing municipalities to increase their efforts to economize energy use and to secure local energy distribution. The law required that municipalities actively promote a reliable and sufficient energy supply, stimulate energy conservation, and develop energy plans [42].

In Linköping, the municipal board immediately made the local energy company responsible for formulating an energy plan. By the 1970s, TVAB was already an established local actor possessing local energy system competence. Local energy conservation activities were not yet common, so there was no real alternative for the assignment. For this reason, officials from the local energy company were made responsible for municipal energy planning (Interview 1, 2, 21, 26, 27, 33).

The fact that the energy plans were formulated by TVAB has to do with historical reasons. TVAB had managed everything concerning energy. Neither the municipal council nor the municipal board knew much about this or tried to manage it (Interview 33).

With this assignment, TVAB also gained power over the content and design of the energy plans. Most interviewees in Linköping also described the local energy plans as the energy company's production plans because they focused on goals and visions that were the same as the company's, *i.e.*, how energy should be produced and distributed in the future. Energy efficiency goals were seldom discussed in the energy plans. Even so, the plans were still treated as political documents representing the politicians' goals and visions.

In later years, other actors in the municipal administration were responsible for developing the energy plan. In the 1990s, the municipal board decided that TVAB should not be the actor responsible for energy planning. The chair of the municipal board said:

> *Even though energy planning is working fine with TVAB doing it, it is not good to have them doing it. You cannot free yourself from the thought that they are not impartial in their investigations* (Interview 31).

However, although other actors were made formally responsible for the energy planning, it was the energy company that in practice formulated the energy plan. This was because the energy company had already gathered the information required for the planning and because the company had sufficient personnel and economic resources for the planning effort.

By controlling the municipal energy planning process, TVAB could control how problems and solutions were articulated in the plans. For example, TVAB could note the problematic situation that energy-reduction strategies were implemented at the expense of increased energy production, which led to reduced company profits (see, e.g., the 1988 energy plan for Linköping).

The benefit of the energy planning was that it entailed informing local actors about the energy system and discussing it with them. The plans were also submitted to the municipal council, resulting in one of the few occasions when the energy system was debated by the council. However, the energy plans did not constitute a powerful control instrument in the hands of politicians, but rather for the energy company. The energy plans also became a tool to coordinate activities in the municipal council with ongoing activities in TVAB.

3.2. Enrolling the City Council and Avoiding Conflicts

The city council debated energy issues from time to time, e.g., in relation to big investments or major changes in tariffs. For TVAB to control the energy system, it also needed to control debates and decisions on the city council and city executive council. For this, TVAB has a resource on its board, whose members are elected politicians who can influence how issues are raised, discussed, and decided on in the city council and city executive council. Some respondents even described TVAB's board members as constituting "the company party" because they were often united across traditional party boundaries when it came to addressing energy issues:

> *We usually say that in this municipality we have not only the traditional parties but also the "company party." Those who are on the board agree and take the company's stand against the municipality. They don't see their role as defending the public interest, but rather as defending the company from the municipality* (Interview 37).

The chair of TVAB's board described how board members often needed to explain and justify TVAB actions to the city council (Interview 31). One board member explained that, as TVAB board

members, they usually forgot about their party affiliations (Interview 6), and others explained that identification with the TVAB board was stronger than identification with the political party (Interview 6, 34 and 37). For example, when TVAB had the goal of expanding into new areas, such as biogas production (described below), all representatives from the TVAB board advocated the expansion on the municipal council regardless of their party affiliation. TVAB's board consisted of elected politicians that also sit on the city council. In general, the TVAB board was described as "strong" and the governance from TVAB's owners as "weak".

In Linköping, the company has rarely been governed by owner directives, which have tended to be general, the most specific concerning the required rate of return. The chair of the municipal executive council claimed that the municipality was not interested in using owner directives (Interview 31). Traditionally, dialogue has been emphasized in dealings with TVAB and local politicians have preferred to see the company as part of the municipality rather than as a self-governing body. The company representatives took different positions regarding that issue. Sometimes they emphasized that they were responsible for the company and acted in its interests, for example, when discussing the goal of keeping prices low. The same representatives might later emphasize the company's independence from its owners, for example, when explaining why the company did not lower its prices further when profits were high. The owner's governance was characteristically exercised via informal meetings. Interestingly, these informal contacts were described by both the owner's and company's representatives as a way to increase their power. When asked how this could be the case, a city council chair active in the 1990s said:

> *But in a way you can say that it was a strategy of TVAB management not to have too many formal requirements, but instead to try to manoeuver between the municipality's informal demands. In this way, they avoid legal binding contracts, such as general agreements. . . . For me as the chair it was also beneficial that we didn't need to put all the details into a contract, because that would probably be too difficult and lead to strong resistance* (Interview 32).

At the same time, there were calls to formalize the process to make it more transparent. A politician, active at the same time as the chair quoted above, said:

> *A formal process would eliminate "corridor guiding"—decisions made opaquely and hidden directives from the city council chair. It would be a more transparent process that is easy to follow* (Interview 33).

One reason for weak owner control that many respondents suggested was that the municipality lacked knowledge of the energy system and could not control various external issues such as taxes, emission standards, and competition. Many politicians also claimed that the deregulated electricity market had reduced their ability to govern the energy system. For example, one politician said:

> *When it comes to the energy system, it is run in competition today, and we have no ability to govern that* (Interview 34).

This view was supported by TVAB's board chair, who said:

> *Power over electricity and heating lie beyond both the municipal council and the executive council. Due to the deregulation, the power is held by the market player when it comes to production and sales. When it comes to the grid, the power is held by the state authorities . . . Yes, the power is formally retained by the city council, but they probably leave these issues to TVAB to decide, because that is where the knowledge is* (Interview 4).

Most interviewees emphasized the importance of technical knowledge when explaining why TVAB retained most of the power and more or less determined the development of the energy system. Lack of competence was then cited to explain why the city was a weak owner that did not interfere in the development of the system.

TVAB was generally described as an important technical resource with sufficient capacity, knowledge, and interest to take responsibility for technical support in the municipality. The energy company's technical competence was an important explanation of why it could exercise power over the local energy system. Common explanations for why the politicians often could not or did not exercise power were that they lacked appropriate technical knowledge and that the electricity market deregulation had shifted power from politicians to customers.

3.3. Expanding the Market

The final example of how representatives of TVAB could act as system builders is that of their actions concerning the introduction of a biogas system in the local context. Here, we will discuss how this was possible and why TVAB acted as it did.

As described above, the energy company TVAB had overall responsibility for electricity, waste, water, sewage, and other services in the municipality. The methane/biogas by-product resulting from sludge processing in the sewage treatment plant had been used for heating since the 1960s. In the 1970s, anaerobic digestion (in which biogas is intentionally produced) became an interesting waste treatment alternative in the company. Later, the use of biogas in district heating or transportation was investigated after the oil crises of the 1970s [5]. In the 1970s and 1980s, TVAB also became interested in a planned natural gas pipeline to complement the already produced biogas [5]. As the pipeline was never realized, the plan to use biogas complemented with larger amounts of natural gas was abandoned.

Parallel to the biogas investigation in TVAB, the municipality was seeking a solution to a specific problem of local air pollution. In the city center, high levels of air pollution had been recognized in an area where the only vehicles were public transport buses [5]. As a result, politicians and civil servants investigated solutions such as moving the buses out of the city center and, foremost, replacing the bus fuel with a "green" alternative. In the early 1980s, the health risks connected with diesel were debated in Sweden, legitimizing solutions such as non-conventional fuels [43,44]. Both politicians and technical professionals discussed how to define what constituted a "green" fuel and, as a result, the municipally owned public transport company responsible for the city bus traffic contacted TVAB. Together, the public transport company, TVAB, and municipal representatives initiated a pilot study with five biogas buses from 1992 to 1994.

Although TVAB had been an essential partner in the pilot project involving biogas-fuelled buses, it did not drive it [5]. Instead, the energy company began intensive work of its own when it started investigating and planning for large-scale biogas production. For TVAB, interest in large-scale biogas production mainly concerned opportunities to use anaerobic digestion for waste management purposes, connecting biogas production with other company functions. That is, in this context the company was primarily interested in waste management, not "green" transportation fuels as such (Interview 2, 13 and 41).

In developing the biogas production (*i.e.*, the initial phase of shaping the considered sociotechnical system), TVAB faced several critical problems whose handling required various resources. The first problems were biogas production and by-product disposal. The production problem concerned the fact that large-scale biogas production had not been tested before in Linköping. In addition, access to the amounts of substrate needed was problematic. Although biogas had previously been produced in the water treatment plant, the new initiative was for large-scale upgraded production of biogas, which was no longer a by-product. The use of the by-product of biogas production as a bio-fertilizer had earlier been questioned by farmers because of its unknown contents. Without farmers willing to receive the by-product, disposal would become a problem. The production and by-product issues were strongly interconnected. To address them, TVAB enrolled several actors and used its client network as a resource. The energy company had connections to a large nearby slaughterhouse that sent large amounts of organic waste far away for treatment. The energy company offered to handle the slaughterhouse's waste as an alternative to sending it elsewhere. That is, TVAB could charge the slaughterhouse to treat its waste while using it as substrate for biogas production (Interview 2, 5, 29, 31, 38). In this case, the

energy company used its client network as a resource to obtain the substrate it needed. Furthermore, energy company representatives contacted the farmers' interest organization. In collaboration with the slaughterhouse, TVAB representatives convinced the farmers (*i.e.* the slaughterhouse customers) to accept the by-product as a bio-fertilizer. In this case, the by-product actually resulted from the farmers' own operations. In the biogas subsidiary that the energy company later established, the farmers' interest organization and the slaughterhouse were partners (Interview 2, 12, 31, 36). This case illustrates how close collaboration among network actors was needed to initiate large-scale biogas production.

Another critical problem concerned selling the gas. This issue is distinct as the actor needing to be convinced was the owner, *i.e.* the municipality. Enrolling the municipality was important for several reasons. First, the municipality had to approve both biogas production and the establishment of the new subsidiary. Second, it had to approve the use of biogas in public transport buses; if not, most of the gas would not be sold (Interview 5, 12, 13, 29, 30, 31). In both the production and sale of the gas, the municipality was thus a key actor. As mentioned above, municipal politicians had long been discussing the use of green fuels in public transport. Although various fuels had been investigated, the question of what fuel to use remained unanswered. In attempting to convince the municipality of the advantages of biogas at the same time as other fuels were being investigated, the energy company was addressing not only the problem defined by the municipality, *i.e.* a "green" fuel for the local bus fleet. In addition, it was promoting biogas production as a solution to another problem, namely, waste management. Initiating large-scale biogas production, the company claimed, would enable the development of new methods to treat organic waste. One of the production leaders described the situation:

> *You could not do one thing without the other. Without solving the waste problem, there was no material for the production. Without selling the gas, you could not handle the waste. It was all connected* (Interview 12).

In this case, TVAB used its expertise as a resource in convincing the municipality of the advantages of biogas production. Promoting biogas as a solution not only to the air pollution problem defined by the municipality but also to a waste-disposal problem made large-scale biogas production a strong proposal. In addition, TVAB's ability to prepare a proposal for a fuel not previously produced on a large scale in Linköping illustrates the company's use of economic resources (*i.e.*, time and money) and technical expertise to reach its goal.

4. Discussion

The three examples illustrate that it was mainly representatives of TVAB who acted as a system builder in the studied case. According to Hughes [9], system builders are actors essential for realizing the development of a system. To realize their vision, system builders must solve critical problems and unite divergent interests within a complex set of actors by mobilizing resources. In other words, system builders control the system and its expansion. In our examples, TVAB representatives were able to use the organization's resources and enroll other actors into supporting its vision. TVAB's representatives, both in conducting energy planning and in developing a biogas system, saw the opportunity and used its resources (*i.e.*, skills, knowledge, and network) and interests to formulate energy plans, investigate energy system development, and create a proposal for the owner (*i.e.*, the municipality) while possessing sufficient implementation power to realize its plans. By controlling these plans, TVAB representatives were able to set the agenda, define problems, and suggest solutions. Although different representatives were active in different meetings and stages of the processes, they maintained a "company perspective" and drove the processes in the same direction.

As discussed above, TVAB possessed significant internal knowledge, skills, and experience regarding energy; moreover, in the municipality, most energy knowledge was gathered within TVAB. Because of their knowledge and experience, energy company representatives have often been involved

in diverse policy processes and been able to influence municipal energy policy in general. Although TVAB was not obliged to develop the biogas system or even, since the 1990s, to formulate energy plans, it in fact remained the only municipal actor with sufficient competence and capacity to initiate and undertake such efforts. According to Hughes, a system builder needs a vision of the system and must be able to initiate, investigate, and plan the vision's implementation, which TVAB representatives demonstrated they could do in the biogas case. For example, the disposal of the bio-fertilizer produced by biogas production illustrates a critical situation that company representatives had to address to realize system development. By connecting actors to its interests and thereby enrolling these actors, the system builder was able to forge broad collaboration that supported its system development proposals and visions.

As discussed above, as a municipally owned company, TVAB was governed by a political board whose members represented political parties and, in theory, could influence the direction of energy policy. However, we have seen that the politicians on the company's board tended to see themselves primarily as energy company representatives rather than as representatives of the municipality or the political parties. The TVAB board members were thereby important company allies when seeking to enroll politicians from the municipal council and the municipal board.

The examples presented here illustrate how the system builder function was dependent on various resources. To plan and initiate technical systems, the energy company representatives mobilized several resources. Financial resources and technical competence were vital in this respect, but in the biogas case client networks were also important in addressing critical problems. Hence, a willingness to change was insufficient in itself to create change; rather, all the resources of the energy company were essential to its acting as a system builder.

In particular, technical competence proved important. TVAB's technical knowledge was essential when planning and presenting proposals to the municipal council. In the biogas case, the energy company had the ability to investigate this fuel option for years before it became a proposal ready for decision-making. In the decision-making process, the municipal council was presented with an already tested, locally produced biofuel that also played an important role in waste management in the energy company. The same holds for the energy planning, where the municipal council decided on the already finalized energy plan.

In earlier studies on system builders, the analysis had been done in relation to expanding systems, but in our case we showed how system builders act also in relation to mature systems. The energy planning case provides a good example of how system builders can act in a system that is not necessarily expanding but is in a stagnation phase. In this phase, the system builder's role is more one of protecting an established system than of implicitly expanding the system or inventing new ideas. In formulating the energy plans, the TVAB representatives could decide what problems and issues to include and what issues to exclude. In this way, they could emphasize the distribution and production of district heating, simply excluding issues of energy efficiency that did not advance the company's more production-oriented goals. In discharging this more protective role, the goal of the system builder is to exclude certain actors and interests from the process rather than enroll them. If the energy company representatives had enrolled, for example, an energy advisor, the advisor would emphasize the need for energy efficiency and that would have shifted attention to an issue that the company would prefer was ignored.

Summerton [11] has criticized the focus on heroic individuals (often men) in earlier research of large technical systems. In our example, it is clear that system building is a collective process involving many different representatives from the energy company. To achieve their goals concerning technical system development, the TVAB representatives mobilized various resources and thereby collectively acted as a system builder. However, these resources were available to the energy company at least partly because it was a limited company and market actor. As a limited company, TVAB earned income from its customers, making it independent of political decisions and budget prioritizations. The company's own resources could be mobilized in order to investigate its own ideas and solutions.

Although the company was owned by the municipality and in practice governed by a political board, it tended to act very independently of its owner and to mobilize resources available within the company to realize its own vision.

In Table 1, we summarize the findings from our three examples.

Table 1. Summary of challenges and characteristics in the examples.

Example	Challenges	Identified Characteristics
Energy planning	Coordinate processes	Knowledge of the energy system; interest to defend the system; skills to integrate interdependent components
Debates in city council	Avoid conflicts and enroll actors	Maintaining a company perspective; use of network; knowledge of owner's requirements
Biogas	Expanding the market	Knowledge, skills and networks in two technical systems contributed to recognized opportunity; interests to expand the market through coordination

In sum, we can conclude that a system builder is characterized by:

- the ability to act as one unit and drive processes in one direction, despite the multitude of individuals representing an organization;
- the ability to act in various decision arenas and coordinate processes to support its interests;
- the ability to use knowledge, skills, and experience to control and coordinate a multitude of policy processes; and
- recognizing opportunities to enroll actors and combine knowledge and experience from different sociotechnical systems.

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Appendix 1: Interviewees

Interview No	Title	Organization	Active Period
1	CEO	TVAB	1992–1999
2	CEO	TVAB	1977–1991
3	Deputy CEO	TVAB	2002–2011
4	Chair of the Board	TVAB and City Council	2003–2009
5	Deputy Chair of the Board	TVAB and City Council	Current
6	Member of Board	TVAB and City Council	1995–2007
7	Project leader, district heating	TVAB	1965–2011
8	Environment engineer	TVAB	Current
9	Project leader	TVAB	Current
10	Environment communication	TVAB	Current
11	Consultant and project leader	TVAB	Current
12	Project leader	TVAB	Current
13	Production manager	TVAB	Current
14	HVAC	Municipal housing company	Current
15	Environment coordinator	Municipal real estate company	Current

Interview No	Title	Organization	Active Period
16	HVAC	Municipal real estate company	Current
17	Electrical engineer	Municipal real estate company	Current
18	Deputy CEO; CEO	Linköping Public Transportation	1987; 1988–1994
19	Personal manager	Linköping Public Transportation	1981–1994
20	Energy advisor	Municipal Building department	1997–2010
21	Energy advisor	Municipal Building department	1980–1987
22	Energy advisor	Municipal Building department	1981–1988
23	Agenda 21 coordinator	Municipal Environment department	1997–1999
24	Agenda 21 manager	Municipal Environment department	1995–2000
25	Environmental manager	Municipal Environmental department	1994–2013
26	Environmental manager	Municipal Environmental department	1981–1991
27	Planning architect	Municipal Planning department	1980–1991
28	Planner	Municipal Board's planning unit	1986–1997
29	Planning manager	Municipal Planning department	1977–2005
30	Traffic planner	Municipal Planning department	1981–1993
31	Chair Municipal Board	Social Democrat	1991 and 1995–2000
32	Chair Municipal Board	Center party	1977–1979 and 1985–1988
33	Member of City Council	Moderate party	1970–2002
34	Member of City Council	Left party	1994–2002
35	Substitute member of City Council	Moderate party	1989–1994
36	Member of City Council	Center party	1985–2004
37	Member of City Council	Center party	Current
38	Member of city council	Environmental party	Current
39	CEO	Regional public transportation company	1981–2002
40	Member of Board	Regional public transportation company	1985–1992
41	Biogas consultant	Municipal administration	In periods from 1986
42	Official	Consultant in traffic planning	Current
43	Manager	Swedish Transport Administration	Current
44	CEO	Linköping Public Transportation	1972–1988

Appendix 2: Interview Guide

A. Background information

- Education, how long at this position, previous employment
- Your organization's role in general
- Do you have any unpublished documentation regarding the project/process?

B. Initiation

- Can you give a brief history of the project/process?
- How did discussion get started?
- When?
- Where?—who owned the issue?
- Which actor?
- Which issues were on the agenda?
- Education, how long at this position, previous employment
- Inspiration from other projects/actors

C. Problem definition and solutions

- Was there a specific problem to be solved?
- Did the problem change over time?
- Were other problem formulations dismissed?
- Which actors brought in what problems?

- Which solutions were presented?
- Which actors suggested what solutions?

D. Actors and driving forces

- Which actors were involved and why?
- In what way did different actors get engaged?
- Which interests did different actors bring in?
- Where did the discussions take place?—in which arena?
- Which actor was a driving force?
- Which actor was in opposition?
- Which actor was seen as driving the process?
- Actors who dropped out

E. Actors and cooperation

- How did other actors outside the process act (such as other municipalities, energy companies)?
- What did the network look like (involved actors, meta-governor)?
- Actors that created alliances
- How were new actors enrolled?—by whom and why?
- Cooperation culture?

F. Final

- Something to add
- Other people to interview
- Can I come back if I have further questions?

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