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# Obduracy and Change in Urban Transport—Understanding Competition Between Sustainable Fuels in Swedish Municipalities

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**Abstract:** Within the renewable transport transition, a number of alternative technologies have emerged creating competing visions of how to reduce fossil fuel dependence. This paper examines the dynamics of competing fuels in two Swedish municipalities where electric buses have emerged, threatening incumbent biogas-based bus systems. While in Linköping, actors are resistant to the promise of electrification, in Malmö the shift to electrify urban buses has already begun. Here, the theoretical perspectives of obduracy and sociotechnical imaginaries are used to analyze obduracy and change in Linköping and Malmö, showing how the local contexts of these two municipalities influence obduracy or willingness to change. In Linköping, perceived connections between the biogas-based bus system and local infrastructures of renewable waste management and organic food production cause actors to place biogas buses at the center of a sustainable future region, while in Malmö linkages to the gas network (which also distributes natural gas) cause actors to question the sustainability of the fuel in use and opens up the city to welcome new electric vehicle tests. These examples show how fuel alternatives interact with each other in the wider renewable energy transition.

**Keywords:** obduracy; sociotechnical imaginaries; urban public transport; electric vehicles; biogas

## 1. Introduction

Within the global renewable energy transition, the transportation sector plays a particularly challenging role as the vast majority of all vehicles are driven by fossil fuels. A number of alternatives have emerged, including numerous biofuels as well as electric and fuel-cell vehicles, promising the potential for a more sustainable future. In the last few years, electric vehicles especially have gained widespread international interest, particularly because these vehicles can simultaneously reduce energy demand through more efficient engines, while replacing polluting fossil fuel vehicles with cleaner and quieter alternatives [1]. However, limited research has explored the way that these expectations surrounding alternative fuels can lead to discord within this transition. This paper addresses this gap by focusing on the emergence of electric vehicles in the Swedish context and how this interacts with existing biofuel usage. Studying this interaction in Sweden is of particular interest as policy reports have identified the increased efficiency of electric vehicles as a necessary step to achieve the intended ambitious transition to a fossil fuel independent vehicle fleet [2]. Urban buses are specifically identified as a prioritized space for electrification, as these vehicles have predictable routes allowing smaller batteries and planned charging infrastructure. Furthermore, electric buses are also identified as a solution to air quality concerns in city centers where bus traffic is heaviest [3–5]. In conjunction with these policy aims, the number of projects testing electrified public transport bus lines in Swedish cities has grown rapidly, adding to a longer historical trend of electricity use in public transport through

trams, trolley buses, and commuter trains. Many Swedish municipalities and regions have increased emphasis on the role that public transportation plays in creating a desirable place to live, prioritizing public transportation in city planning [6]. It is this particular electrification trend that I will focus on in this paper, with an emphasis on how this causes tensions in the existing public transport sector where the vast majority of bus kilometers are already driven by biofuels [7]. In fact, the public transportation sector is the area of transportation where the greatest progress has been made towards fossil fuel independence, particularly because of the role of public procurement [8].

This paper focuses on the emergence of urban electric buses in two Swedish municipalities that have built up urban bus systems based specifically on compressed biogas, Linköping and Malmö. The treatment of the electrification trend in historically biogas municipalities provides particularly interesting material for study because like electricity, biogas-based bus systems also require complex infrastructures for fueling and gas-specific buses (as compared with some other liquid biofuels which can utilize the same infrastructures as diesel and petrol). Furthermore, because of the limitations for transporting compressed biogas (because of its large volume and need to maintain pressure), biogas production was also often viewed as a preferred solution for municipalities that could utilize the biogas close to where it was produced, causing many Swedish municipalities to invest in biogas production and transportation infrastructure in the beginning of the 21st century [3]. Today in many of these municipalities, the relationship between growing interest in electricity and a stable biogas system have led to a contested future of the urban bus system with many actors unsure of which alternative could be part of a better society. This analysis contributes to the literature of sustainability transitions by exploring how non-fossil fuel alternatives come into competition with each other. The case studies show how this competition goes beyond the question of which alternative is more sustainable to include considerations of the embeddedness of infrastructures of fuel production and provision, actor's involvement and visions and expectations of the future. By highlighting these dynamics, we can better understand how to navigate the interactions between non-fossil fuels to help contribute to a more sustainable future transport system.

This paper will specifically focus on electricity and biogas urban buses in Linköping and Malmö, Sweden, questioning why these two municipalities have different interpretations of the role that biogas and electricity should play in their public transport system. In Linköping, a medium sized Swedish city and home to the largest national biogas producer, Tekniska verken, the biogas-based bus system emerged partially due to the role of the municipality as a systems builder [9]. Here, many actors remain hesitant to consider a future transport system that does not utilize the locally produced biogas, contributing to resistance to adopt electric vehicles [10]. Malmö is the third largest city in Sweden, and has also invested heavily in building a biogas-based urban bus system, however, here the city is undergoing a gradual shift to electrification of urban bus lines. The aim of this paper is to explore what factors have led to disparate treatments of urban electric buses in these two seemingly similar cases. This paper will employ the concept of obduracy as used in the work of Hommels [11], to explore the dynamics of local biofuel systems that influence the willingness (or unwillingness) of actors to consider a shift to electrification. Within this framework, obduracy can be described as the characteristic of sociotechnical systems that enable them to endure in their current state despite new influences. By using the concept of obduracy (and malleability to provide a counterpoint), I will explore these two cases to better understand why these two municipalities have reacted differently to the promise of electric vehicles. Furthermore, this study will help explore the way that renewable fuels compete and complement each other, highlighting an interaction that is likely to become more frequent as renewable fuels play a bigger role in the transport sector.

Hommels' framework of obduracy can help address this question because it provides three theoretical models to explain the dynamics that create stability in systems causing them to resist change. Using these models, we can understand what aspects of the Linköping biogas system make it more obdurate than the Malmö system. Additionally, the concept of sociotechnical imaginaries will be used to consider how visions and expectations influence these dynamics, emphasizing the role of

social aspects in sustainability transition [12–14]. Sociotechnical imaginaries are relevant here because these collectively held visions of the desirable future have considerable influence on the practices and expectations of actors involved in these public transport systems. The normative aspect of these imaginaries works to dictate what future actors think should come to pass, influencing the way that they work to achieve these futures, a process which can influence obduracy or malleability. On the one hand, a strong imaginary that places biogas at the center of a future sustainable region will create obduracy in the municipality and encourage actors to maintain this fuel ensemble, while on the other, a sociotechnical imaginary that identifies electric buses as a central aspect of an improved urban center can lead to malleability by destabilize the biogas system and encouraging actors to enact an electric vehicles future.

This paper will also emphasize the role that sustainability profiles of biogas and electric vehicles play in the public transport future in Linköping and Malmö, building on an extensive literature that questions the usefulness of performative definitions of sustainability [15–17]. Sustainability is a central aspect of the ongoing transition where the conflict between these two fuel types in urban public transportation buses is framed within wider aims of achieving a fossil fuel independent vehicle fleet for all road transportation by 2030 [18]. Sustainability has become an important part of Swedish culture, as evident nationwide through commitment to achieving 16 environmental goals and locally through sustainability policies and plans. Sustainability is even taught to children in schools from early childhood [19]. However, sustainability is a complicated issue with sustainability of both biogas and electricity dependent on the specific context of production and usage. For example, electric vehicles are only as sustainable as the electricity supply that drives them. In the Swedish context, electricity is primarily produced from hydro, nuclear, and wind power contributing to the perception that electric vehicles are a climate friendly choice [20]. This expectation of sustainability, however, is not totally straightforward as increased electrification of vehicles may increase national electricity demand and require imports from other parts of Europe that rely heavily on coal for electricity generation, thus exporting the pollution from one country to the next. Furthermore, the increased size and usage of batteries has also called into question the impact of extraction of rare earth metals to power electric vehicles [21]. Biogas, in contrast, also has a sustainability profile that is determined by the substrates used for its production. These many factors highlight the complexity in the way that sustainability is defined. These perceptions are dependent on local context as well as actors positioning as shown in the analysis of these two cases.

First, I will introduce the conceptual framework including the perspectives of obduracy and sociotechnical imaginaries. Section 2 introduces a discussion of the methodology used in the study, while Section 3 will layout the two cases in detail. In Section 4, I will discuss these cases using Hommels' three models of obduracy with a particular focus on how sociotechnical imaginaries contribute to obduracy or malleability. In the final section, overarching themes and conclusions will be explored.

### *Obduracy in Sociotechnical Ensembles*

This study will utilize the concept of obduracy to explore the contrasting treatments of electric buses in Linköping and Malmö. By exploring how actors in Malmö and Linköping view biogas and electricity in the consideration of the future of the system, we can start to understand the complex relationship between these biogas sociotechnical systems and the possibility of a shift to electrification. Specifically, this paper will draw on the conceptualization of obduracy as used in the work of Hommels [11] to evaluate the tendency of some artefacts and ensembles to resist change. As Hommels [22] describes this thinking:

But despite the fact that cities are considered to be dynamic and flexible spaces, numerous examples illustrate that it is very difficult to radically alter a city's design: once in place, urban structures become fixed, obdurate. As a consequence, urban artefacts that are remnants of earlier planning decisions, the logic of which is no longer applicable, may prove to be annoying obstacles for those who aspire to bring about urban innovation. (pp. 323–324)

In this manner, planning decisions become dependent on what came before and are subject to the logics and materialities produced by their outcomes. Hommels' work developed in relation to studies of urban planning and infrastructure, however, here we apply this to a slightly different type of structure, namely heterogeneous systems of fuel provision. For this reason, I describe the bus systems under consideration as sociotechnical ensembles, a term which highlights the fact that the pursuits of engineers (and other types of system builders) "are best described as heterogeneous system- or network-building rather than as straightforward technical invention" [23]. This conceptualization is considered especially relevant for the cases at hand because of the complex nature of transport systems which necessarily include roads, buses, fuels, politicians, bus drivers, (and so on) inherent in a transport system. For this reason, 'sociotechnical ensemble' is considered a useful term to describe the complex and networked nature of the objects of this study, as opposed to artefacts which Hommels uses in her work.

In addition to Hommels' framework, I also turn to the theoretical perspective of sociotechnical imaginaries [12] to attempt to explain the processes of obduracy and change in these two cases. Sociotechnical imaginaries can be defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" [24]. Here, I use sociotechnical imaginaries as a way of explaining the role that visions and expectations play in processes of obduracy and change. I see this as two-fold: imaginaries can both contribute to obduracy by stabilizing actor's commitment to a certain technological choice (in this case biogas), or drive processes of change through imaginaries surrounding new technologies (in this case electricity). These imaginaries influence obduracy or malleability through practice by impacting everyday actions that either stabilize the incumbent system or open up to a new alternative. Sociotechnical imaginaries examine the way that future visions of actors and social groups are enacted in the planning process because actors are prone to choose alternatives that align with their vision of a desirable future. This interaction parallels the way that the social sphere is already envisioned within Hommels' obduracy by incorporating the ways that socio-materially built understandings of the desirable future impact planning decisions, similarly to the way that Hommels relates to socially held remnants of previous planning decisions. As Jasanoff explains:

By turning to sociotechnical imaginaries, we can engage directly with the ways in which people's hopes and desires for the future—their sense of self and their passion for how things ought to be—get bound up with the hard stuff of past achievements, whether the material infrastructures of roads, power plants, and the security state or the normative infrastructures of constitutional principles, juridical practices, and public reason. [24]

Through this quote, she demonstrates how imaginaries can help lead to obduracy in incumbent ensembles because of the way these interact with material infrastructures and practices of transport planning. Elsewhere, research has explored the myriad of ways that visions influence technological transitions [25]. This is especially relevant in situations where technological alternatives are in competition, requiring actors to decide what alternative they support and consequently placing their resources behind that alternative.

Although imaginaries and expectations are not explicitly named in Hommels' models of obduracy, they are frequently implied through the way that she relates to actors' frames, care and values. Hommels' framework emphasizes the role that the social plays in contributing to obduracy, and in the analysis section I will describe how sociotechnical imaginaries are part of this process because of the way that they connect technological choices with certain desirable social values. Thus, rather than choosing a technology, actors are choosing what type of future they want to come to pass. First, however, I will introduce the three conceptual models of obduracy that comprise this framework: dominant frames, embeddedness, and persistent traditions. In formulating these models, Hommels' builds each on a single case study of a large-scale planning project in a Dutch municipality. She builds these models to show three different ways of conceptualizing obduracy that can be used independently

with their own set of terms and concepts. However, she also argues that “one model alone cannot sufficiently explain obduracy in the urban context” [11]. For the purpose of examining the urban bus ensembles in Linköping and Malmö, I will engage with all three models. As strengths and weaknesses exist with each, this is an attempt to improve the understanding of the dynamics of obduracy and change in these cases.

‘Dominant frames’ is used to refer to fixed ways of thinking utilized by groups of actors when considering the design and use of technological artefacts [11]. These frames contribute to obduracy by locking groups of actors in to thinking about the problem in a specific way [26]. The concept of dominant frames refers to the obduracy that occurs when different groups of actors emphasize different ways of thinking about the problem and refuse to compromise. The second model, ‘embeddedness’, emphasizes heterogeneity of cities by highlighting interactions between human and non-human elements of sociotechnical ensembles [11]. This is inspired by the approach of large technical systems and especially the notion of a ‘seamless web’ [27], accentuating the fact that urban technical ensembles, such as public transport systems, are embedded in larger networks of infrastructures and social and political relations. ‘Persistent traditions’ is the third and final model of obduracy introduced by Hommels. Hommels defines this concept as referring to the enduring character of an ensemble where planning decisions are influenced by “longer term processes that are deeply rooted in culture at large” [22]. Essentially, persistent traditions create obduracy when long-term effects of early planning decisions influencing the future development of a technology, partially due to the way that these decisions impact the cultural aspects of the community. In Section 3, I will analyze the explanatory power of these three models in relation to illuminate the obduracy and malleability of urban bus systems in Linköping and Malmö.

## 2. Methods and Materials

Linköping and Malmö were chosen as contrasting cases to study the role of obduracy in local urban transport ensembles for several reasons. Both municipalities have begun exploring the idea of electric buses despite a strong history of biogas use. While Linköping has a unique role as a frontrunner in national biogas development [9,28–30], Malmö arose as a contrasting case during the initial Linköping interviews. Malmö provides a noteworthy contrast because despite a biogas dominant urban bus ensemble, the municipality has also acted as an early mover in electric bus adoption.

In order to better understand the cases of Linköping and Malmö, analysis focused on interviews with key actors involved in public transport decision making in each municipality. Interview subjects included actors from both the municipal and regional level of governance, including both civil servants and politicians. In both case studies, regionally owned public transport authorities are responsible for providing urban bus transportation, which is then run by bus operators who own and operate the buses and employ the drivers. I interviewed representatives of these organizations as well as the biogas suppliers, who also play a central role in ensuring success of these urban bus ensembles. The distribution of interviews for each case is shown in Table 1.

**Table 1.** Interviews completed in Linköping and Malmö.

Actor Group	Interviews in Linköping	Interviews in Malmö
Municipal actors	2 politicians, 2 civil servants	1 politician, 2 civil servants
Regional actors	1 politician, 1 civil servant	1 politician
Public Transport Authority	1 Östgötatrafiken	1 Skånetrafiken
Biogas provider	2 Tekniska verken	1 E.ON
Bus operators	1 Transdev	1 Nobina
University Researchers	3 Linköping University	-
Agricultural interest group	1 The Federation of Swedish Farmers	-

It is worth noting that the number of interviews was not symmetrical between these two cases (14 in Linköping and 7 in Malmö). This was due largely to the result of snowballing, which led to a multitude of diverse additional suggestions in Linköping and limited recommendations in Malmö. This could be contributed to the different perceptions of the biogas contra electric bus discussion underway at the points in time where interviews took place. While interviews in Linköping were completed during 2017 alongside another contentious project on electric buses, in Malmö interviews were completed during early 2018 after the decision to electrify transport had already been taken. Interviews were semi-structured, following an interview guide organized around key themes focusing on the actors' views concerning the benefits and barriers for the biogas and electric bus ensembles as well as their plans and visions for the future. All interviews, save one, were completed in person and lasted between 25 and 90 minutes. These interviews were analyzed to establish the existence of obduracy or malleability of these two urban bus ensembles, as well as how these are influenced by perceptions of the future. These interviews were then transcribed and coded using atlas.ti software to determine common themes. Interview material was used to show how actors' individual visions show obduracy or malleability through their expectations about biogas and electricity in the future system, as well as their imaginaries surrounding these two fuels through the way they discuss the relative merits of these two fuels.

### 3. Urban Bus Ensembles in Linköping & Malmö

This section provides an overview of the current urban bus ensembles of Linköping and Malmö, showing how biogas and electricity are imagined by actor groups, and how these two ensembles can be understood as obdurate and malleable counterparts.

#### 3.1. Linköping—Biogas's Biggest Producer

In Linköping, biogas was first introduced as a potential solution to the energy crisis of the 1970s and was eventually adopted as a joint solution to municipal waste management and air pollution problems in the city center in the 1990s [31]. At the time, the municipality owned both the waste and energy management company (Tekniska verken) and the public transport provider (then LiTA, a predecessor to Östgötatrafiken) [29]. The involvement of these three actors (the municipality, Tekniska verken, and LiTA) in the decision-making process contributed to biogas's viability as a transport fuel. While Tekniska verken worked to develop an efficient biogas digestion process, LiTA (and later Östgötatrafiken) provided a guaranteed market for its sale [9]. This relationship resulted in the introduction of the first biogas buses in the 1990s and the subsequent growth of the biogas urban bus system, leading to a 100% biogas bus fleet in 2016 [32].

Due to early investments, energy company Tekniska verken is currently the largest biogas producer in Sweden. However, they also provide other utilities to the municipality and surrounding area including waste management, electricity, water, broadband, and central heating and cooling [33]. This results in a company that is central to everyday activities of citizens creating a general awareness of the company. Furthermore, the company remains municipally owned creating a wider local interest in Tekniska verken's success. This interest materializes through the role of the company board which is composed of local and regional politicians, creating a formal connection between the politics of the municipality and Tekniska verken's business. Previous research, however, suggests that this dynamic tends to benefit the company as board politicians identify with their role in Tekniska verken and even tend to act in the company's interest in other political arenas [9]. This dynamic contributes to obduracy because board members are able to work to preserve the biogas-based bus system through their other political assignments. Through this relationship, Tekniska Verken becomes embedded in the governance structure of the municipality, which contributes to the obduracy of the urban bus ensemble. This role contributes to many actors' hesitance to shift away from biogas in the bus ensemble, because of the investments that the company and the municipality have made in developing this ensemble. As a municipal politician describes, "I think it is important that we have also made great progress in

biogas in this region so I think it is pretty important that we stick to it because if we switch over to electricity (in buses) now it will be hard to manage" (Interview L6). This quotation shows how one actor views the biogas history as a motivation for obduracy by connecting the possibility of electrification to the previous investments. In this case previous 'progress' is used as a motivation for avoiding future progress because of the notion that electrification would be an undoing of the current biogas ensemble. Elsewhere, a Tekniska verken employee explicitly relates this obduracy to the economic argument stating that "We have made really large investments, 500 million (Swedish crowns, which is equivalent to around \$52 million US.) to achieve the biogas system we have. If you consider the economic aspects of it also then if we stop using biogas buses then all of that money is *pssht* gone". (Interview L8). This quote indicates a perception that a shift in transport forms would render this investment a waste, undoing the sunk cost of previous economic investments.

In Linköping, the biogas ensemble has also developed connections with other urban infrastructures, including the waste and agricultural systems. Much of the biogas in Linköping comes from household organic waste, collected by Tekniska verken in green bags for household use that state, "your food waste will become biogas!". Furthermore, the biogas process creates a by-product in the form of organic fertilizer which is returned to local agriculture. This by-product places biogas at the center of local nutrient recycling loops, where key nutrients for farming such as nitrogen and phosphorous are extracted through crops, sold in the stores, consumed by locals, disposed of, and then returned to local farms through the digestate fertilizer. This nutrient flow, however, is just one possible pathway (which disregards, for example, the distant sourcing of many fruits and vegetables), but it creates a powerful image that contributes to the positive perception of biogas in Linköping. As elaborated by Tekniska verken's chairperson, "it is something that makes the case much more valuable in comparison with other fuels because it has advantages through the biofertilizer that returns nutrients to nature. There is no other fuel that does that" (Interview L9). This quotation indicates how these connections influence actor perceptions because biogas does something that other fuels cannot, providing an additional link for regional sustainability. This understanding also contributes to the obduracy of the system because actors voice concern that abandoning the biogas bus system will have negative effects for these connected systems. This is described in a second quote, once again from a Tekniska verken employee who describes, "People don't understand that it is thanks to the fact that public transportation in Östergötland runs on biogas that we also have organic agriculture in the region" (Interview L8). This quote implies a perceived cause and effect relationship between biogas production and organic agricultural production, providing an important motivation for maintaining a biogas-based system that continues to support these other resources. Another way of looking at it is that these linkages between the biogas ensemble and these other socio-technical systems actually contribute to a stronger system.

These connections between the biogas system and municipal governance, economic investment, and resource loops make a strong case for an obdurate biogas-based urban bus system in Linköping, despite increasing interest in electrification. At the time of the interviews, there was a clear interest in electrification among regional politicians who had also decided that an electric bus trial should be carried out somewhere in the region, but not where (Östgötatrafiken announced plans to electrify some bus lines in both Linköping and its sister city Norrköping as of January 2019 but the specifics of this plan are still unclear.). As a number of the interviews show, these dynamics are also present in the future imaginary of urban transport in Linköping, where many actors believe that biogas is central to the sustainability of the future region. This imaginary contributes to the obduracy because it leads to a sort of reconciliation in the way that actors consider electrification (for a more in-depth discussion of this see Mutter 2019 [10]). Here, many actors agree that more cities will have electrified bus fleets but perhaps not in Linköping because of concerns that this would threaten the other systems that biogas is connected with. This imaginary contributes to the obduracy of the system by providing resistance to a fuel shift. However, many actors understood that many types of fuel would be necessary to achieving a fossil fuel free future. As one university researcher describes, "if you want to look at it from the perspective of a fossil free transport system, I think it's kind of an uncontroversial as well. Realizing

that we need a number of different alternatives to fossil fuels and we need to make as efficient use of each alternative as possible" (Interview L1). This quote identifies one recurrent perspective within the actor's imaginaries in Linköping, that many fuels will be needed. However, despite this perspective the biogas imaginary remains central with most actors adamant that one of these fuels should be biogas, contributing to the stability of the biogas ensemble.

### 3.2. Malmö—*Biogas History, Electrified Future?*

Malmö is the third largest municipality and was one of the first municipalities in Sweden to introduce gas buses, putting two into circulation already in 1988 when the natural gas network came to Malmö [34]. Biogas use in Skåne (the region within which Malmö is situated) has grown steadily since the early 2000s, with continuous expansion to new production plants. Today, Skåne is one of the biggest biogas-producing regions in the country, contributing 21% of total Swedish biogas in 2011. In Skåne a relatively large percentage of produced biogas goes into municipal central heating, with the remainder upgraded for use as a vehicle fuel [34]. Biogas has contributed substantially to Skånetrafiken's progress towards fossil fuel independence, with all city buses in the region, including in Malmö, powered by renewable fuels already in 2015.

The biogas ensemble in Malmö is quite different from that in Linköping, partially due to the dispersed organization of actors, infrastructures, and resource flows. The biogas used in Malmö's city buses is purchased from the German owned energy company E.ON. As an international company that operates in many parts of Europe, E.ON has a different profile than Tekniska verken, with wider international linkages. As part of this, E.ON. sources the biogas used in Malmö's buses from some 15 producers in Sweden and Denmark (Interview M2, E.ON representative). The result of this dispersed organization is that E.ON does not have political and social linkages to local businesses in the same way that Tekniska verken does. This organization also contributes to the way that biogas is perceived in Malmö, where actors seem skeptical about the sourcing of the biogas in city buses. This is partially due to the dispersed origin of the biogas but also to the connection to the international gas pipeline that enters Sweden from Denmark and travels up the west coast. This pipeline creates an infrastructural connection between Malmö and Danish biogas producers, which are perceived to be less sustainable than Swedish producers since they are more likely to use crops grown specifically for fuel generation, an activity which takes away from land for food production. Furthermore, the pipeline is also used to distribute natural gas (as part of the vehicle gas mix), creating some uncertainty around the percentage of biogas versus natural gas that goes into the actual vehicles. In an interview with one municipal politician, it is clear that this uncertainty influences how the bus system is understood, "one way to put it is that when you go to put the fuel in the vehicles, a part of it is natural gas rather than biogas. So, from that perspective, we are talking about a fossil fuel we will get rid of for the most part" (Interview M7). As this quotation indicates, some actors perceive the current system as unsustainable because of the understanding that it is dependent on natural gas. This perception that electricity will be displacing a fossil fuel makes a noticeable impact in the way the relative sustainability is defined and contributes to a malleable biogas-based bus system. This is particularly evident when compared with the Linköping case, where the biogas system is perceived as contributing to a more sustainable region. In Malmö, not only do these connections not exist, malleability is also due to the interpretation that the biogas system has negative effects by supporting fossil fuel consumption through natural gas.

In Malmö, support for electrification has taken a stronger hold than in Linköping. In 2015 Skånetrafiken began experimenting with electrification in Malmö by introducing a biogas-electric hybrid line as the so-called 'Malmö express', and has already agreed to adopt full-electric buses in two routes [35]. The electrification of these first lines has progressed swiftly and the first electric buses hit the road at the end of 2018. This is only the first step in a larger electrification process, where Skånetrafiken has stated that green electricity should be the preferred choice of fuel to encourage the reduction of energy use and carbon dioxide emissions [36]. This gradual transition was also indicated

in interviews with city planners, who suggest that additional electric lines will not be far behind (Interview M4, municipal civil servant).

During fieldwork in Malmö, the decision to swap biogas for electricity in these bus lines was not viewed as controversial with all actors supporting this decision. One factor contributing to this lack of concern is the general lower energy efficiency of biogas engines contra electric engines. On average, a biogas car uses 0.64 kWh of energy per kilometer driven while the average usage for electric cars is 0.15 kWh per kilometer [37]. These technical concerns contribute to the ease at which actors are willing to accept electrification as this is considered a more sustainable choice. As a representative from Skånetrafiken states, “biogas should find a niche where this great fuel can be used in a better way than to ‘burn 70% for the crows’ (This is a Swedish idiom used to indicate wasted heat, in this case due to low efficiency of gas combustion engines.) and use at most 30% of the energy. There should be a more rewarding use than to upgrade it for vehicle use” (Interview M1). In this statement she is problematizing the sustainable framing of biogas that is prominent in the Linköping case. From a sustainability perspective, she argues, there should be a better way to use the fuel so that it contributes to sustainable society as a whole. This actually parallels the overarching imaginary in Linköping, that all fuels will be needed for a fossil free future, however in this case a judgement on the ‘right fuel’ for city buses necessitates a shift away from biogas towards electricity which is perceived as a better alternative.

Both the willingness to accept electric buses and the lack of concern for biogas phase out show a lack of obduracy in the biogas urban bus ensemble in Malmö. This malleability is also evident in interviews with key actors which present a widespread imaginary that electricity is the best solution for Malmö city buses. As one regional politician clarifies, “since we started looking into it, it was clear that customers were interested in electricity for energy efficiency’s sake but also for environmental reasons because electric buses are quieter and have no emissions at all” (Interview M6). This quotation motivates the argument that electricity is the best alternative in urban environments, a point which is central to the future envisioned by Malmö actors. In another quote, a Skånetrafiken employee connects this more concretely to the future saying, “In ten years, 2027, 2028 we will have just received our last batch of electric buses so that all of urban buses in Malmö will be electrified” (Interview M1). Here, the imaginary becomes concretized in the perception that all urban buses will be electrified in ten years. In this case, the public transport imaginary also connects to a specific definition of sustainability which favors electrified buses as a way of reducing the air pollution in cities, improving public health. Here social sustainability is also mentioned by some actors, who motivate this as a reason for supporting technological solutions such as bus rapid transit that connects different neighborhoods. However, as in the Linköping case, actors in Malmö also imagine a future public transport system that goes beyond fuel choice to offer a better society for residents. Autonomous vehicles and improved transport connections with nearby Copenhagen were also introduced as concrete technical solutions to provide a better public transport system in the future, although these technologies were framed as improving ease of transport rather than sustainability.

#### 4. Discussion—Obduracy and Malleability in Urban Bus Ensembles

The municipal perspectives on electricity contra biogas, as discussed in the previous section, indicate obduracy in the biogas urban bus ensemble of Linköping but malleability of the biogas urban bus ensemble of Malmö despite a shared history of biogas development. In the section that follows, I will return to the three models of obduracy as introduced by Hommels’ to determine how they can be applied in the cases of Linköping and Malmö.

##### 4.1. Dominant Frames of Biogas

Hommels uses the model of dominant frames to explain the phenomenon where groups of actors involved in a planning process become tied to one specific way of defining or framing a problem so that the meaning prescribed to the artefact (or ensemble) becomes quite fixed [22]. This process

creates obduracy by reducing the willingness of these actor groups to compromise by entertaining alternative solutions that do not conform with this framing. One way that dominant frames can be used to understand biogas bus ensembles is through the multiple usages for biogas, including electricity production, combined heat and power production, and as a vehicle fuel. In Malmö, biogas is used in a few different applications while in Linköping, biogas is primarily framed as a fuel specifically for public transportation. In this case, this framing of 'biogas for public transport' creates strong obduracy in the urban bus ensemble because this framing locks actors into the assumption that in order for all of the positive effects of biogas to be maintained urban buses must run on biogas. From my perspective, this works as a dominant frame because it perpetuates "constrained ways of thinking" [11]. By remaining stuck to the framing of 'biogas for public transport' actors are viewing the whole ensemble as under threat by the prospective of electric buses as indicated by a quote from a Tekniska verken employee who states that "I think it is really important that we understand that we can't swap out all biogas buses for electric buses because then we will waste everything we have done in the last 20 years!" (Interview L8). This quotation shows the perceived loss that a shift to electrification would cause for Tekniska verken, making their previous years of work irrelevant. In reality, the biogas system could continue to contribute to the regional nutrient cycle, organic agricultural production, and sustainable waste management even if electricity is adopted because the biogas can simply go to other uses.

This analytical use of 'dominant frames' however, contrasts Hommels' example of Hoog Catharijne because in Linköping there seems to be consensus between all actor groups supporting the 'biogas for public transport'. This lack of a competing frame indicates a limitation in using this model to analyze biogas ensembles, because although obduracy is inherent in the stability of the 'biogas for public transport' frame it is not a result of a conflict between groups in the same manner. However, it is still clear that in many cases actors' opinions are influenced by their positions in this case. In Malmö, however, actors do not conform to this frame, perhaps because of the fact that a large percentage of biogas is already used in heating and power, allowing actors to consider what could be called a 'biogas for heat and power' frame. This is suggested as one alternate usage for the biogas that will be displaced by electric buses, while shifting the fuel to regional bus traffic is another (thus sticking with the 'biogas for public transport' framing). These contrasting but not necessarily competing points (since actors do not seem particularly concerned about what the biogas will be used for) show that there is still some interpretive flexibility around biogas.

In some cases, sociotechnical imaginaries can contribute to the power of dominant frames through the way these frames connect with expectations about "how life ought, or ought not, to be lived" [24]. In many cases, these frames lock actors into specific expectations about what the future will and should be. For example, the 'biogas for public transport' frame links the future of public transport to the future of sustainability in the region through the commitment of this use for biogas. In other words, by failing to accept alternative uses for biogas, actors come to perceive biogas buses as central to the continuation of the system of waste recycling and nutrient reuse that is important for regional sustainability. This is evident from several of the quotes introduced earlier, where actors specifically mention that it is the fact that biogas is used in public transportation that has contributed to organic agricultural production in the region, and the expectation that shifting to electric buses will waste the prior investments. These perspectives link all the benefits of the biogas ensemble to the continued use of biogas in public transportation. One university researcher indicates that this is somewhat intentional: "It's kind of an advertisement for biogas, the buses. And it's a justification why we spend local taxpayers' money in sorting systems to make the organic wastes available for biogas production. You benefit from it as a local citizen" (Interview L1). This dynamic and the resulting dominant frame interact with the imaginaries of biogas, where many actors are adamant about the continued use of biogas for public transportation.

#### 4.2. *Embeddedness of the Biogas Urban Bus Ensemble*

The second model Hommels introduces focuses on the embeddedness of artefacts and ensembles in the complex heterogeneous infrastructures of cities. Hommels characterizes embeddedness by explaining how this notion “refers to the increasing interrelatedness of socio-technical elements as a way to account for urban socio-technology’s resistance to change” [11]. She especially emphasizes how this obduracy often goes beyond material factors to include planning structures, legal regulations, and viewpoints of the actors involved. Embeddedness was evident in both urban biogas ensembles in a multitude of ways. One common form of embeddedness in both cases was the embeddedness within infrastructures of biogas generation and provision. This physical embeddedness ties the urban bus ensembles to a greater network of resource provision in the municipalities, but also influences social aspects of the ensemble such as public support. In Linköping, this network results in a biogas bus ensemble that is deeply embedded in wider local networks of waste management and agricultural provision through the biological resources that pass through the biogas digestion process. In this case, biogas is produced locally with locally sourced substrates, resulting in a by-product nutrient rich fertilizer which can be used in local agricultural production. Through these processes, the biogas ensemble is embedded in the socio-material infrastructure of resource reuse through its contribution to the local life cycle of key organic nutrients. By bridging the gap between organic waste products and organic agriculture, the biogas process creates an important linkage by returning key nutrients such as nitrogen for future agricultural growth. Furthermore, this embeddedness is also central to the way that biogas is interpreted as contributing to local and regional sustainability as discussed in the following section. This embeddedness contributes to the obduracy of the biogas ensemble and creates resistance to the possibility of electrification.

In Malmö, in contrast, the biogas used in city buses is imported from further afield, connecting the ensemble to a different and more dispersed material infrastructure of the gas distribution network. Although this linkage results in an embeddedness within infrastructure, the materials that flow through this are not connected to local value creation of waste treatment and organic agriculture. Rather than connecting the biogas system to resource reuse as in Linköping, the gas pipeline facilitates a one-sided flow from international producers to the biogas buses and contributes to an imaginary where the gas in the buses is unsustainable. This socio-material infrastructure contributes to a malleable system by detaching the urban bus network from the biological nutrient loop by placing literal distance between the producer and consumer. In this example, the embeddedness in the gas network also impacts relevant actors’ views of the biogas ensemble. Instead of believing that the biogas buses contribute to local development, actors often view the gas in the buses as coming from elsewhere, in this case either natural gas or Danish biogas. As a result, this type of embeddedness actually contributes to malleability and enables willingness to accept electric buses as an alternative.

Sociotechnical imaginaries also relate to the model of embeddedness because imaginaries are one of the many socio-cultural aspects that artefacts and ensembles can be embedded in. In the case of Linköping, the biogas ensemble is embedded in a biogas imaginary as well as the waste and agricultural systems of the region. As previously explained, this imaginary connects the future of biogas as a fuel for public transportation to the continued health of these interlinked systems. In Malmö, in contrast, the biogas imaginary is instead largely replaced by a future imaginary of electric buses. Here, this imaginary helps actors to overcome the potential for obduracy in the pre-existing biogas ensemble through the promise of a better future offered by electric vehicles. In this sociotechnical imaginary, electrification of urban buses reduces the overall energy demand and contributes to cleaner and quieter urban centers. The interlinkage between the material biogas ensemble and the intellectual imaginary is also made within the imaginaries literature where Jasanoff [38] writes, “By inquiring into imagination as a social practice, we follow the embedding of ideas and cultures, institutions, and materialities, whereby the merely imagined is converted into the solidity of identities and the durability of routines and things”. Here Jasanoff implies that imaginaries are in turn embedded in the material, cultural and

institutional aspects of an ensemble. This indicates that embeddedness goes both ways, and shows how imaginaries can relate to obduracy or as she calls it "the durability of routines and things".

### 4.3. Persistent Traditions

Persistent traditions address the deeply rooted cultural aspects of obduracy that (in contrast to dominant frames) focus on collectively held values that transcend social groups. One such difference that emerged in these two municipalities was the way that sustainability was understood and treated within urban planning. Although sustainability as a concept only emerged about 20 years ago, it plays a central role in the public transport planning in these two municipalities where there is a clear difference in the way it contributes to urban development. Furthermore, sustainability also emerged as a key theme in descriptions of the desirable future. Each of these cases represent interesting examples of sustainability and have been explored as such in previous literature. Linköping has gained widespread attention primarily because of their sustainable resource use and their biogas system [9,28–30,39]. Malmö, in contrast, has a more general sustainability profile since the launch of the Bo01 housing project in the Western Harbor in 2001 and more recently with aims of becoming "Sweden's most climate-smart city" by 2020 [40–42]. These different profiles mirror the way that sustainability is defined in each case.

In Linköping, sustainability is directly related to sustainable resource use and nutrient cycles. In interviews, biogas is championed largely for its contribution to sustainability by bolstering the ecological health of the municipality and its surrounding region, as previously discussed. Fallde [28] has even suggested that for these reasons biogas became synonymous with environmentally friendly public transport already in the 1990s. Biogas helps to facilitate renewable waste management by re-using nutrients from organic waste, and to facilitate organic agriculture through the use of digestate by-product as a fertilizer. In this way, biogas essentially becomes a linkage connecting sustainability from three platforms: Public transportation, waste management, and organic agriculture, to form a single understanding of sustainability as contributing to a closed local resource loop. Emphasis on this type of sustainability is evident in interviews with key actors who frequently tout the advantages that the biogas system promotes in the region. In this manner, the persistent tradition of sustainability supports the obduracy of the biogas bus ensemble by emphasizing the way this has and will continue to contribute to a sustainable region. In this way, electric buses are once again challenged as they are not sustainable in the same way since the electricity network is internationally linked.

In Malmö, in contrast, a different tradition of sustainability is emphasized by many actors, who focus on the long-standing role of the city as a 'test bed' for sustainability projects [43]. This focuses on the active willingness of the municipality to explore alternative solutions to sustainability problems, including through pilot projects with new technologies. The previously mentioned Bo01 was one such experiment in the form of a sustainable housing exhibition and this tradition is also present in the thinking around the electrification of city buses. As noted in the case introduction, actors are excited to test out electricity in local buses, highlighting the superior opportunity of electric buses to decrease energy demand and contribute to a favorable city environment. In this way, actors in Malmö are also prioritizing a different type of sustainability through the use of electric buses which have their own profile because of reduced in place emissions and noise. Actors in Malmö note that this is an important factor because this also contributes to social sustainability by improving public health.

In this case, the way that electrification is introduced can also be seen as an example of the 'test bed' tradition because of the way they have incorporated innovative technology into the first electric routes. As of current plans, the two initial lines will utilize different charging technologies to explore the opportunities of each. The benefit of this decision is introduced by a representative from the bus operator, Nobina, who noted "it is really smart, actually, to get to test both types of technology. So, then we know which seems to work best for the problem at hand" (Interview M3). In this manner, Malmö is not only testing out electric vehicles, but is also experimenting with potential technologies to find which should be upscaled with the electrification of additional lines creating the

best and most sustainable future. In this case, the interpretation of sustainability that is prominent in Malmö and that which is prominent in Linköping show two local persistent traditions around sustainability. Furthermore, in Malmö, the understanding of sustainability actually contributes to the weak obduracy of the case by encouraging experimentation with emerging technologies. In this case one of the models of obduracy is contradicted because the 'persistent tradition' we are considering here actually supports a malleable system by placing value on the testing of new types of artefacts or ensembles. Furthermore, persistent traditions are connected to sociotechnical imaginaries in both cases through the way that these perceptions of sustainability dictate the preferred fuel choice. As previously mentioned, the commitment to biogas in Linköping is linked to the perception that this fuel choice will help facilitate a continued sustainable resource loop in the future region, while in Malmö the 'test bed' mentality supports the switch to electric buses which offer a newer and more modern alternative. In this way, the cultures of sustainability that have developed in the region impact the imaginaries of which fuel will bring about the better future.

## 5. Conclusions

As Hommels [11] writes, "obduracy is never an intrinsic property of technology, but technologies are made obdurate". This quote is pivotal to Hommels work and the three models of obduracy by showing how obduracy is not necessarily a static quality but rather a process achieved by actors (human and non-human) surrounding the artefact or ensemble. This paper has sought to explore the practices of obduracy and change within two biogas-based urban bus ensembles in Linköping and Malmö, Sweden including how actors' imaginaries of transport futures play an important part in these processes. Here, the theoretical perspective of obduracy was used to examine resistance to change in these systems. Obduracy can be defined as the way that artefacts or ensembles "become fixed, obdurate" causing them to become "annoying obstacles for those who aspire to bring about urban innovation", while malleability is used as a term to illustrate a lack of obduracy [11].

Specifically, this paper has attempted to explain why actors in these two municipalities have responded so differently to the emergent emphasis on electrification of urban buses. While in Linköping, the biogas bus ensemble has remained obdurate, in Malmö, electrification has begun to replace biogas in urban buses indicating a malleable system. By applying Hommels' framework to these two cases, I have shown how the models of dominant frames, embeddedness and persistent traditions can also be used to understand the divergent treatment of electric vehicles in these cases. This analysis shows how the obduracy of the biogas ensemble in Linköping is largely due to the linkages between the biogas bus ensemble and other regional systems including waste management and organic agriculture. These linkages, which can be understood through the model of embeddedness create a stronger biogas ensemble and are connected to the persistent tradition of sustainability which emphasizes the importance of the resource cycle for regional sustainability. Furthermore, these linkages also add power to the dominant frame of 'biogas for public transport', since this frame is based on the perception that if electric buses are adopted the benefits that come from these linked systems will be lost. In the Malmö case, however, these linkages do not exist because of the dispersed sourcing of the biogas and instead the biogas ensemble is embedded in an international fuel pipeline. This leads to a malleable system by contributing to the perception that the biogas is a less sustainable choice and allowing actors to instead favor electric buses. These contrasting interpretations show how choice of non-fossil fuel goes beyond the sustainability of the alternatives to incorporate these contextual factors. This lesson is essential for the wider sustainability transition because it emphasizes the importance of combining different solutions where they are best suited.

Hommels' uses these three models, which can also be understood as different mechanisms to achieve obduracy to analyze different artefacts, although they do not exclude each other. Thus, I have attempted to apply them all to the material in an attempt to better understand what is happening in these cases. As the analysis shows, however, not all models fit equally well. While the model of embeddedness seems to provide a good fit showing how the interlinkages between the biogas

ensembles and other infrastructures and networks lead to obduracy and malleability, the models of dominant frames and persistent traditions are not as successful in their explanatory power here. Dominant frames is somewhat limited in its applicability, primarily because the framing of 'biogas for public transport' lacks a contrasting frame in the Linköping case and retains interpretive flexibility in the Malmö case. Persistent traditions, in contrast, provides somewhat of a challenge because these biogas bus ensembles have developed in the last 20–30 years. This provides a relatively short basis for what can be considered 'persistent' including the understandings of sustainability. By framing these urban bus networks as complex ensembles of humans, technologies, infrastructures, and ideas this analysis has highlighted a new level of abstraction within these models by showing how they can also contribute to malleability. For example, in Malmö, the embeddedness of the ensemble in an international biogas network and the persistent tradition of acting as a test-bed have resulted in a malleable urban bus ensemble where imaginaries of the future shift to the benefits of urban electrification. These cases build on Hommels' work by highlighting the importance of local contexts as contributing to malleable or obdurate ensembles.

By introducing the theoretical perspective of sociotechnical imaginaries this paper has demonstrated the critical role that visions and expectations of the future play in the actors' willingness to consider emergent technologies. In the analysis section I have explored how sociotechnical imaginaries in the cases of Malmö and Linköping pay a part in the malleability or obduracy of these two urban transport ensembles, contributing to a heightened understanding of how processes of change are impacted not only by material factors, but also by perceptions of value. In Linköping, the presence of a strong imaginary around biogas is instrumental to the obduracy of the system because actors view the biogas bus ensemble as part of a desirable future where a cycle of resource reuse is maintained. In Malmö, this connection does not exist allowing actors to instead envision an imaginary of electric buses. Hommels' [11] explains this phenomenon by writing "the unbuilding of cities does not only involve handling steel and concrete, but it also involves dealing with those ideas, policies, traditions and commitments that have become embedded in the socio-technical layout of cities". Hence, obduracy is not a result only of the material relationships of artefacts and ensembles, but also of ideational expectations and visions of the future which interact with all three models Hommels introduced.

Another conclusion to be drawn from these comparative cases is the different ways that sustainability can be defined within urban transport ensembles. While in Linköping, biogas was viewed as a sustainable fuel and a central part of a future renewable transportation system, in Malmö it was strongly connection to natural gas, which is a fossil fuel and was abandoned in favor of electrification. This shows contrasting definitions of what a sustainable future system should be. While in Linköping, the sociotechnical imaginary surrounds biogas as a central component of regional resource loops that contribute to renewable waste management and organic agriculture, in Malmö the 'test bed' encouraged trying a newer and potentially better option. Here, electric vehicles were touted as a central part of the sustainable future because of their efficient engines and lack of emissions. These contrasting definitions seem particularly important with relation to Swedish national transport goals which intend aim for a fossil fuel independent transportation system by 2030. These cases provide contrasting pathways for how this future can be achieved, but also problematize the expectation that sustainable urban transportation can only look one way. Rather, these examples highlight that change processes are diverse, which complicates planning processes to achieve such wide-spanning goals.

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