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Competing Transport Futures: Tensions between Imaginaries of Electrification and Biogas Fuel in Sweden

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Abstract

The choice of fuels has frequently been at the center of debates about how a future low-carbon mobility system can be achieved. This paper introduces two visions of biogas fuels and electricity using material from interviews and documents in Swedish transport. These visions are analyzed as interrelated sociotechnical imaginaries. To better understand the way visions of biogas and electric vehicles (EVs) dynamically shape and condition each other, four dimensions of sociotechnical imaginaries are further developed: spatial boundedness, temporality, coherence and contestation, and the socio-material relations they are associated with. Imaginaries of biogas and EVs differ with respect to these characteristics. The biogas imaginary is made up

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of locally bounded visions of the desirable future, showing how imaginaries can be fragmented and contested, often because of their embeddedness in local socio-material systems of resource use. This local boundedness is exemplified by contrasting cases of contested biogas imaginaries in the Swedish municipalities of Linköping and Malmö. The imaginary of EVs, in contrast, is more uniform nationally and even influenced by international expectations that in the future vehicles will be shared, electric, and autonomous. The qualities of these imaginaries shape the way they interrelate and coevolve as sociotechnical changes of the transport system unfold.

Keywords
sociotechnical imaginaries, transport futures, electric vehicles, biofuels, multiplicity

Introduction

The decarbonization of the future transport system is regarded as a key challenge to combat the climate crisis. Transport accounts for around 40 percent of all greenhouse gas emissions in Sweden (Trafikverket 2019). Visions of what a low-carbon transport future could look like range from substituting fossil fuels with biofuels, electricity, or hydrogen to fundamental changes in mobility arrangements including the organization of our settlements, new types of transport services, and new modes of transport (Fletcher, Longnecker, and Higham 2019). But how are these diverse and sometimes contradictory visions and expectations of future transport mobilized by different actors, and how do they merge into new dominant narratives or become marginalized? How are these visions enacted in the present? These issues are decisive for how the transformation of our transport system unfolds and contributes to the mitigation of climate change.

The choice of fuels has frequently been at the center of debates about a transition toward low-carbon transport (Martinez Arranz 2017). Different types of fuel require different infrastructures and sociotechnical arrangements of fuel production and supply, are linked to different practices of vehicle use, and rely upon different types of industries and vested interests. Contestations over the choice of fuel are also salient in the Swedish transport system, which is internationally at the forefront of low-carbon transport with 30 percent of overall energy use already supplied by renewable fuels

(European Commission 2020). Two fuels stand out in this respect: Biogas made from organic waste and electricity. While biogas has become an important renewable fuel with a strong basis in many cities and regions in Sweden, a powerful new discourse about the electrification of transport has emerged, gaining worldwide traction and creating challenges for fossil fuels and established biofuels alike.

These two cases illustrate a wider trend of contestations about alternative fuel futures as the pressure of climate change increases. Obviously, these fuel alternatives do not evolve independently of each other. A successful buildup of an urban electric vehicle (EV) infrastructure will make parallel investments in a biogas transport system less likely and will confine biogas to other uses. Moreover, a transport system relying on locally produced biofuels will require very different complementary arrangements of organic waste collection or feedstock production than a transport system integrated with the central electricity grid. Both alternatives evoke different transport futures that cannot be easily aligned. In this paper, we investigate the imaginaries of such futures around the fuel-alternatives biogas and electricity and the way these imaginaries dynamically interrelate. The frictions between these visions of transport futures cannot be dissociated from their socio-material relations. We argue that the different (social, material, spatial, and temporal) qualities and contestations of these imagined futures around biogas and electricity are associated with specific arrangements of low-carbon transport that become enacted in the present. The aim of this paper is to gain a better understanding of the dynamic interrelation of emergent alternative futures of biogas and electricity-based transport. This also provides new insights into how transitions toward more sustainable infrastructures unfold in other fields.

The role of visions for the enactment of possible futures in the present has been extensivly investigated within science and technology studies (STS) (see McNeil et al. 2017; Konrad et al. 2017), and the concept of sociotechnical imaginaries offers a particularly promising framework for analyzing the making of alternative transport futures. In Jasanoff's (2015b) words, the concept provides "a powerful new angle on world making" with a "focus on where transformative ideas come from, how they acquire mass and solidity, and how imaginations, objects, and social norms (. . .) become fused in practice" (p. 322). While the original concept has predominantly focused on the intimate relation of such imaginaries with national politics, our cases draw attention to the contestations between coexisting imaginaries and their rootedness in different socio, material, and spatial relations. By focusing on the dynamic interrelation of imaginaries, this article also

contributes to the further development of the concept of sociotechnical imaginaries.

In the following section, we will discuss this concept in the context of literature about the role of visions and expectations for sociotechnical change. Drawing on recent discussions in this field, we will further develop a set of dimensions that are characteristic of different imaginaries and that potentially create tensions between them. We will then present and analyze the dynamics between imaginaries of biogas fuels and electric transport in Sweden. Furthermore, we consider these dynamics within the local contexts of Swedish municipalities of Linköping and Malmö, showing how the imaginary of biogas and its relation to electrification varies between and within these cases. Based on this empirical analysis, we will discuss the insights of our sociotechnical imaginaries perspective for an unfolding low-carbon transition in Swedish transport and the implications for the further development and application of the concept of imaginaries.

Contested Sociotechnical Imaginaries

Several concepts of imaginaries, visions, expectations, or narratives have been developed within different strands of science, technology, and innovation studies to better understand processes of sociotechnical change and the way imaginations of the future act as a cultural resource to shape actions in the present (for a genealogy of such concepts, see McNeil et al. 2017). One method for examining these visions is through a "sociology of expectations" that investigates how collective expectations of the future shape scientific and technological development and build obligations and agendas (Borup et al. 2006; van Lente, Spitters, and Peine 2013). Expectations involved in sociotechnical change can refer to particular projects, the future of a technology, or broader frames and master narratives for change processes, such as the importance of solar energy for mitigating climate change (Kriechbaum, López Prol, and Posch 2018). However, in our study of alternative transport fuels, we are also concerned with the wider ideas of desirable futures evoked by different technologies. By understanding the visions surrounding biogas as a fuel and EVs as sociotechnical imaginaries, we can examine the "abstract yet durable" aspects of our collective understandings of the future while recognizing that these are also contested and built on specific promises and expectations (Jasanoff 2015a, 24). Jasanoff (2015a, 4) defines such imaginaries 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." More specific expectations, for example, whether cheaper and longer-lasting batteries will be available for cars soon, become part of these imaginaries, even if they do not fully define them.

Increasingly, the concept of sociotechnical imaginaries is applied to study energy transitions (Ponte and Birch 2014; Eaton, Gasteyer, and Busch 2014; Smith and Tidwell 2016; Jasanoff and Kim 2013; Sovacool et al. 2020). One problem sometimes encountered in these studies is the emphasis of sociotechnical imaginaries on the national level where "powerful instruments of meaning-making and goal-setting" exist (Jasanoff and Kim 2009, 123). Jasanoff and Kim (2009, 120) ask: "How do national S&T projects encode and reinforce particular conceptions of what a nation stands for?" Moreover, research such as Jasanoff and Kim's (2009) analysis of nuclear energy mostly focuses on the futures evoked in relation to one specific technology. Our aim to analyze the tensions and interrelations between imaginaries of biogas fuels and the electrification of transport thus requires further extensions and differentiations of Jasanoff's concept. Four specific qualities of imaginaries appear to be particularly important for the dynamics of their interrelations: the potential boundedness of imaginaries to different spatial scales, not only the national level; the contested nature and internal coherence of imaginaries; the entanglement of imaginaries with the materiality of the technologies they refer to; and temporalities in the development of imaginaries. All four dimensions have been introduced in the literature on imaginaries but have not been combined to analyze the coupled dynamics of sociotechnical change linked to different imaginaries.

Spatial Boundedness of Imaginaries

Although most studies of sociotechnical imaginaries have focused on the national level, imaginaries may be particularly articulated at different scales, such as regions or cities, or they may aim at sociotechnical constellations with characteristic scalar profiles. The complexity of the adoption of national imaginaries on local scales is shown by Trencher and van der Heijden (2019, 216): "Top-down, nationally formed visions of energy futures," such as a hydrogen-based energy system, may be contested by regionally bounded scenarios (such as a renewable energy future in Fukushima), which are linked to spatial identities and rooted in particular geographies and cultures. Levenda et al. (2019) also observe how national sociotechnical energy scenarios interact with different regional sociocultural and political–economic contexts that in turn may produce regional

variations, embedded in particular values and socio-material contexts, and sometimes be positioned as alternatives to national imaginaries. In a similar vein, Smith and Tidwell (2016, 345) highlight the role of "bounded imaginaries," such as coal and nuclear energy in regions of the American West, in local transitions, which "have the capacity to articulate alternative visions of good societies that challenge the national dominant ones." These studies highlight the way that imaginaries can be rooted more strongly at different geographic scales and articulate scalar relations of transport futures in distinct ways.

Contested Nature and Coherence of Imaginaries

One of our key interests in understanding the making of transport futures is the inherently contested nature of imaginaries, whether within different versions of biofuel futures or between biofuels and electrification. As Jasanoff (2015a, 4) notes, "multiple imaginaries can coexist within a society in tension or in productive dialectical relationship." We are confronted with a plurality of energy futures with multiple, heterogeneous, and sometimes contradictory imaginaries that are often rooted in certain places (e.g., Energiewende in Germany) or solicited by specific actor groups (Delina and Janetos 2018; Delina 2018). As Delina and Janetos (2018, 2) point out, their "meanings and constitutions are continually changed, contested, and shaped" in processes of "negotiating and navigating futures." Sociotechnical imaginaries often turn out to be a "field of struggle over the political imagination" and aim at closing off alternative futures or counter-imaginaries as Sadowski and Bendor (2019, 544) observe in the case of smart city imaginaries.

Imaginaries as Socio-material Assemblages

In contrast to visions and expectations, the concept of imaginaries emphasizes the entanglement of social and material dimensions. As Jasanoff (2015a, 22) puts it, the concept helps to engage with "the ways in which people's hopes and desires for the future (. . .) 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." In a study of sociotechnical imaginaries of coal in Poland, Kuchler and Bridge (2018, 139) are interested in "the material affordances of coal and how these provide particular sociotechnical opportunities for imagining modernity,"

but without losing sight of the "potential instability and ambiguity of materials and objects" (p. 138) whose apparent properties and meaning are not necessarily fixed over space and time. In a similar vein, Mitchell (2011) studies how material properties of oil (succeeding coal as a dominant energy source), including its concentration in a small number of sites and the sociotechnical arrangements required for its extraction and distribution, enable and shape a political apparatus for its governance and, by extension, certain kinds of democratic and undemocratic politics. Materials—such as biogas and electricity, in our cases—are not the "stable foundation of social and political life. They are rather elements of lively and dynamic assemblages that may act in unanticipated ways, serving as the catalyst for controversies and thereby contributing to the transformation of political situations," as Barry (2013, 153) writes. It can be expected that the materialities of electricity and biogas are implicated in similar ways in the relations between these imaginaries and the making of transport futures.

Temporal Development of Imaginaries

A final dimension that has the potential to shape the dynamics between imaginaries is differences in their temporal development. Imaginaries always have a history; they may mature and become increasingly stable or change and sometimes disappear. In his analysis of imaginaries of digitalization, Willim (2017, 57) points out how these imaginaries are always provisional and imperfect and "open-ended, indeterminate, as capacities that are impossible to complete." Jasanoff (2015b, 326) also describes a temporal development of imaginaries where "embedding" is an important step in the progression of an imaginary toward gaining further assent and letting them "acquire mass and solidity" (p. 322). Such a process is often driven by its successful connection with popular interests and identities, linkage with material structures, and alignment with economic, discursive, and political elements (Levy and Spicer 2013, 675). Not least, imaginaries may also differ in the temporal scale of the vision they provide, with some pointing to the near term while others depicting a more distant future, as Sovacool et al. (2020) argue in their comparison of imaginaries of sustainable energy and mobility transitions. Differences in the maturity and temporal structures can also be expected between imaginaries of electrification and biogas in transport.

In our following analysis of the coupled dynamics of biogas and EV imaginaries, we will pay particular attention to these dimensions.

Methods and Materials

This paper's analysis is largely based on the study of transport policy documents and expert interviews. As the focus is on the Swedish perspective, we examined three key Swedish policy reports with the aim of informing fossil fuel vehicle transition, among these a comprehensive Swedish Government Official Report, *Fossil Fuel Freedom on the Road* (Regeringskansliet 2013), which shaped the policy debates in subsequent the years. Moreover, we make use of comments of numerous transport actors on these reports, submitted in a consultation process as part of Swedish law-making procedures. We also consulted contrasting position documents published by electricity and gas industry organizations as well as policy documents at the European and international level. This textual analysis was supplemented with interviews from actors in the Swedish transport sector. Twenty-one interviews focused on the role of biogas and electricity within the urban public transportation systems of the two cities of Linköping and Malmö, which both traditionally have a significant share of biogas in public transport, but respond differently to the new alternative of electrification. These local-level interviews included representatives from the two municipalities, their respective public transport agencies, the companies contracted to operate buses in each city, utility companies involved in supplying biogas, and local and regional politicians. Additionally, the material includes five interviews with national-level actors: the special investigator responsible for the previously mentioned government official report, representatives from Sweden's primary vehicle manufacturers Scania and Volvo, a representative of the Swedish Gas Association, and a researcher with extensive experience working with these two fuel systems.

Imaginaries of Sustainable Transport Futures in Sweden

Biogas in the Swedish Transport System

Swedish national policy has the ambition to achieve a fossil fuel–free vehicle fleet by 2030 and net-zero greenhouse gas emissions by 2050 (Regeringskansliet 2013). As of 2018, biofuels provide for 21 percent of domestic road transport (Swedish Energy Agency 2020). While biodiesel accounts for the majority of these fuels, biogas also contributes substantially and plays a much larger role in Swedish transportation than in other countries (Lönnqvist, Sanches-Pereira, and Sandberg 2015).

Biogas is a biofuel generated from the anaerobic digestion of organic materials. Biogas can be created from many organic substrates including energy crops, household and industrial organic waste, or sewage sludge (Ammenberg et al. 2018). In addition to the gas itself, this process also generates a nutrient-rich digestate by-product that can be used as fertilizer in farming. As an energy source, biogas can have many uses including heating, electricity, or vehicle fuel. For the latter alternative, biogas is upgraded to a methane content of 98 percent, which can be used in internal combustion engines interchangeably with natural gas (Fallde and Eklund 2015).

The use of biogas in the vehicle fleet is particularly prominent in Sweden with around two-thirds of the biogas upgraded for transportation. Public transport is an important outlet for this upgraded biogas, motivating investment in biogas production infrastructure in many regions. Biogas fuels 20 percent of bus kilometers and is the majority fuel in a number of municipalities and regions (Svensk Kollektivtrafik 2018). Compared to other biofuels that are largely imported, the majority of this biogas is locally produced from 98 percent waste substrates (Sveriges Riksdags Trafikutskottet 2018). The Swedish biogas imaginary is thus closely intertwined with sustainable waste management, organic agriculture, and questions of energy security. As a result of these factors, as well as low CO_2 emissions, biogas is central to many interpretations of the future renewable transportation system. Many actors argue for improved policy conditions for increased biogas production and use, including through the *National Biogas Strategy*, a position paper solicited by several of the largest biogas providers (Energigas Sverige 2018).

Biogas usage has remarkable regional variation with some regions using almost no biogas in public transport and others using up to 90 percent. The use of biogas in transport has been driven to a great extent by regional demand and strategic planning from regional transport authorities in combination with tax exemptions at the national level. Municipalities have at the same time acted as "system builders" in creating an infrastructure for biogas production and supply (Fallde and Eklund 2015). Not only has biogas been seen as a new, green enterprise and a concrete support for regional economic development, it has also been regarded as a contributor to the mitigation of both urban air pollution and emission of greenhouse gases (Olsson and Fallde 2015).

Mol (2014) suggests that the regionally uneven development of biogas depends on the boundedness of biogas systems, arguing that the localized nature of these systems has disconnected biogas from some of the

controversies that have emerged around liquid biofuels. This boundedness is also evident in biogas systems in the Swedish case. Factors such as the availability of feedstock from agriculture, the density of the population contributing to organic waste collection, local policies, or the creation of local markets through specific regulations for fuel procurement for public transport can significantly influence local biogas development.

The strong regional embeddedness of biogas imaginaries can also be seen in the case study municipalities of Linköping and Malmö (for more details, see Mutter 2019). Linköping is one of the most advanced Swedish "biogas cities" with all municipal city bus traffic supplied by locally produced biogas. Biogas was viewed by most interviewees as an important part of a sustainable future region because of the way the system utilized municipal waste and contributed to organic food production. Here, the biogas-based bus system is viewed as central to a sustainable lifecycle as biogas is sourced from a municipally owned utility company and is transported from the production facility either by pressurized trucks or a small local gas pipeline. This perception of the biogas system is exemplified by an expert from the municipal utility company who defines a renewable public transport system, saying, "a sustainable public transport system is a circular system where we don't generate carbon dioxide . . . . Biogas (. . .) takes care of the waste problem and we return nutrients (to the cycle) so we can easily compete when you compare with other fuels." This opinion is mirrored by many other actors in Linköping. Thus, the sociotechnical imaginary frames biogas as a necessary part in creating a sustainable region by linking waste management, public transport, and agriculture and associates the imaginary of biogas with a more comprehensive circular economy imaginary that is currently gaining traction (Fratini, Georg, and Jørgensen 2019). Even though attention in Linköping has recently shifted to electrification as an alternative choice for urban public transport, actors remain hesitant to accept this inclination because of what it would mean for the biogas system. As one municipal politician explains, "Linköping is the freaking biogas city, it is not so easy."

In contrast, in Malmö, where biogas use is also high, the imaginary around biogas is much more fragmented and unstable. In interviews with actors here, biogas was more often questioned as a sustainable fuel source, partly due to its material embedding in a transnational gas pipeline and mixing with natural gas. The southern parts of Sweden including Malmö are reached by a natural gas pipeline and, despite local biogas production, much of the biogas is sourced from Denmark through this pipeline where the gas is mixed with natural gas. As one municipal politician explains,

"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 should get rid of for the most part." The problem is compounded by a disconnection between biogas producers and consumers. In Malmö, the gas used for public transportation comes from some fifteen different producers. In this case, the sustainability of gas buses is called into question because it is more difficult to guarantee that the biogas used has the same sustainability profile as in the Linköping case. As a regional politician elaborates, "another concern we have in Skåne is that we import Danish biogas . . . . Danish biogas is special from a sustainability perspective because we want biogas that is mostly based on food waste . . . and that is more uncommon abroad." In Denmark, energy crops are more prevalent and potentially compete with food production. As the above quotation explains, this creates the impression that the use of gas in public transportation actually supports the fossil fuel industry.

Without a pipeline infrastructure, compressed biogas is very difficult and costly to transport over long distances, and substrate collection, digestion, and biogas use have to be situated in proximity (as in the Linköping case). This contributes to the bounding of biogas imaginaries to a local scope. This geographic boundedness is one of the factors that separates biogas from liquid biofuels that are mostly imported from far afield (Sveriges Riksdags Trafikutskottet 2018). Nevertheless, biogas becomes often implicated in critical discourses about the production of other kinds of biofuels and linked to the competition with food production (if agricultural crops are used to produce biogas) or the destruction of rain forests through palm oil production in the global south (see Kuchler 2014).

However, biogas does have a firm place in Swedish national imaginaries about a fossil-free transport future, as a recent government report illustrates. It suggests economic incentives for the upgrading and liquification of biogas to ensure the long-term competitiveness of biogas as vehicle fuel (Westlund 2019). Sociotechnical imaginaries of biogas in Sweden are often coupled with local achievement, regional identities, and the potential of regional economic and sustainable development, as an analysis of Swedish newspaper articles also confirms (Skjølsvold 2012). At the same time, biogas cannot be fully dissociated from a more critical debate about, for example, food versus biofuels, or bioenergy trade as a new form of colonialism (Skjølsvold 2012, 525), even if the Swedish biogas model builds primarily on local organic waste collection.

Imaginaries of Electrification

Despite this long history of regionally produced biofuels, EVs are increasingly perceived as a key part of the Swedish renewable energy transition. EVs are highlighted within Swedish policy documents, particularly because of the increased efficiency of electric drivetrains (Regeringskansliet 2013), which, combined with the renewable sourcing of Swedish electricity, identifies EVs as an important tool in achieving carbon emission reduction targets. Specifically, in 2018, the electricity mix was composed of 41 percent nuclear power, 39 percent hydropower, 10 percent wind, and 0.2 percent solar contributing to a low-carbon mix in Swedish EVs (Swedish Energy Agency 2020). Moreover, electrification is prioritized as a solution for cities (Sveriges Riksdags Trafikutskottet 2018) for its reduced noise and air pollution. EVs function well in the start-and-stop traffic patterns of cities where access to charging infrastructure can also be provided more easily.

The number of EVs has only started to grow in recent years. Global electric car sales have gone up in 2019 reaching a global stock of 7.2 million cars and representing an average 60 percent increase in electric cars in the period from 2014 to 2019. Nordic markets are taking international leadership with 56 percent of all new car sales in Norway in 2019 being EVs. Meanwhile, the rate of electric car sales in Sweden is increasing with 11 percent of the market going to electric car sales in 2019 (International Energy Agency [IEA] 2020). Furthermore, reports suggest that electrification should increase rapidly as more EV models become available. The power industry interest organization Power Circle even goes so far as to suggest that electric cars and plug-in hybrids should dominate the market as early as 2026 (Andersson and Kuhlin 2019). Large car manufacturers such as Renault, Volkswagen, or Nissan have "increasingly made ambitious statements that they will more rapidly reorient towards EVs" (Kanger et al. 2019, 60). Along with cars, the penetration of electric urban buses is also expected to rapidly increase from its current market share of 9 percent (Transport & Environment 2018). Internationally, some cities are already switching their public transport on a large scale to electricity, such as the city of Shenzhen in China, which has adopted electric buses exclusively in their 16,000 bus fleet; similar plans exist for London (Kanger et al. 2019, 59). Together with new specialized EV manufacturers, such as Tesla, emerging industries for battery manufacturing and the increasing overlap of the car industry with information technology companies ("autonomous cars") and electricity utilities ("vehicle-to-grid" solutions) demonstrate the

emergence of a global innovation system (Binz and Truffer 2017) with increasingly vested interests in the future of electric transport.

In comparison with the biogas imaginary, visions and expectations of electric transport appear to be less fragmented, contested, and regionalized. Electrification is presented as an important alternative throughout the country, both in motorized transport generally and urban public transport specifically. This is exemplified in the local case studies of Linköping and Malmö, where there is growing consensus around the need of electrification despite the strong position of biogas in urban public transport. In Malmö, the regional public transport authority, Skånetrafiken, has already started to implement electricity in city buses with the first electrified line in use as of 2018. Here, the electricity imaginary has become dominant, as a representative from Skånetrafiken explains: "We are switching to electricity simply because it is the future, in city traffic, anyway, where we can get the most out of the electricity." In the Malmö case, all the actors interviewed seem to agree with the interpretation that electric buses are more beneficial for the urban routes, much in line with the national imaginary. Even in Linköping, where there seems to be more uncertainty around the role of EVs in the future, many actors agree that EVs are a promising technology for urban transport. As a municipal public servant explains, "I think it feels more modern and hip with electricity than with biogas. Electricity is the solution of the future but I think it would be rather unfortunate if we got rid of the biogas, but then maybe we can use it for something else." This quotation sums up the overarching perspective on electricity among actors in Linköping: they think it is a positive solution for cities as long as it doesn't have a detrimental impact on the current biogas system. Another aspect of this imaginary is the de-emphasis of the sourcing of electricity. As the Swedish electricity mix is largely fossil fuel free, the imaginary of electrification here is aligned with the fossil fuel independent vehicle fleet in both municipalities, with the question of where this renewable energy is generated largely overlooked.

The perception that electrification is the future of transport is mirrored in international reports and policy documents. A survey of 257 mobility experts in five Nordic countries, ranging from manufacturers and industry representatives to public authorities and governments at different levels, indicates that the "rapid electric society" was the most prevalent vision in this group (Sovacool et al. 2019, 5). This vision merges various promises and expectations from the electrification of mobility (rapid charging, electric highways, etc.) with a broader vision of the society becoming fully electric. Policies and documents of the European Union also adhere

to such a narrative. A policy report of the European Commission (European Commission Directorate-General for Energy and Transport 2009, 23) states that the "21st century will most likely see the replacement of vehicles relying on the internal combustion engine by electric vehicles." Furthermore, the recently adopted *European Strategy for Low-emission Mobility* (European Commission 2016) mostly pays lip service to the limited role of biofuels for decarbonizing the transport sector while overwhelmingly focusing on infrastructure rollout and standardization for EVs. In Swedish as in international documents, it is repeatedly pointed out that the future of vehicles is "shared, electric and autonomous" (e.g., Morgon Stanley [2016] or car manufacturer Volvo in the national newspaper *Dagens Nyheter* [2019]). One example of this comes from an interview with the director of public affairs at the Volvo group, who, responding to questions about how he viewed the transport system of 2050, stated, "then I think it is mostly electrified, that we will have gone over to electrified transport entirely!" What is salient in these visions quoted above is how the imaginary of EVs becomes connected to future visions of a much more pervasive electrification and digitalization.

The relation of EVs to the broader electricity system indeed appears to be an important element of the transport electrification imaginary. In the vision of the German energy transition (Energiewende) as one of the foremost international examples, electric mobility is envisioned as an integrated element of a future smart energy system. A recent government report says: "Electric mobility is the global key to a climate friendly transformation of mobility and, in Germany, it is part of the transition toward renewable energy" (quoted from Wentland 2016, 291). Moreover, the electricity system as such is closely connected to national imaginaries of modernity, industrial development (Bridge, Özkaynak, and Turhan 2018), and—particularly in Sweden—sustainability and low-carbon emissions. The largest share of Swedish electricity stems from hydropower and nuclear energy, both closely coupled to historic experiences of industrialization and leadership in engineering (Högselius and Kaijser 2007) and thus to the building of a modern Swedish nation.

However, this homogenous imaginary of electric transport is a rather recent accomplishment and is still not uniformly positive and uncontested. Warnings of an overly optimistic vision of an all-electric future point out that electric need not mean emission-free, as many countries have a significant share of fossil fuels in their electricity mix (Sivak and Schoettle 2017), even if this is not the case in Sweden. In the Swedish context, doubts are also expressed that the capacity of the electricity network might not suffice

in many parts of the country. As explained by a Senior Advisor for Sustainable Transport at vehicle manufacturer Scania, "The challenge for electricity is capacity. We produce enough electricity in the country, but we can lack enough local or regionally produced electricity in some cases and we are lacking the capacity to transfer the electricity when we need it." Additionally, an electric future might be tainted by resource use and environmental damage caused in battery production or by fears of continued low battery ranges and safety concerns (Sovacool et al. 2019).

Discussion: A Dynamic Interrelation of Imaginaries

Let us now turn our attention to how the imaginaries of biogas and electrification are shaped by the dynamics of their interrelation including their internal structure and distinct qualities. In a sense, both imaginaries are simultaneously coproduced in the ongoing socio-material reconfiguration of the transport system. Most of the local and national actors we interviewed referred to both imaginaries and attempted to make sense of how they might impact each other, reconciling how to imagine a biogas future if electricity becomes increasingly dominant. Changing expectations, for example, about the availability and capacity of future batteries or the availability of local feedstock for biofuels, play an important role for building further legitimacy for an imaginary or casting doubt on its credibility. In most cases, the relations between the two imaginaries were more nuanced than the suggestion that one transport alternative would become dominant and the other marginalized, often actors rather imagined new forms of complementarity or merged both imaginaries into new types of imagined future transport systems. This richness of interrelations and interactions of imaginaries is also an important distinction to competing expectations, which often exclude each other (van Lente and Bakker 2010).

Our material shows how the dynamics of interrelations between biogas and electricity are shaped by the characteristics of these imaginaries as described in the conceptual section—the affordances of the specific socio-material arrangements they are part of, their affiliation with different spatial structures, and the temporal characteristics that differ between, for example, emerging imaginaries of an all-electric future and more mature imaginaries of biofuel use. In the remaining part of this article, we discuss the differences in the spatial, temporal, and material profiles of the two imaginaries of biogas and electrification in transport and the way they impact how both imaginaries develop in interrelation with each other.

The empirical cases show how imaginaries relate to space and scale in characteristic ways, depending on the way they are bounded by their locality (Smith and Tidwell 2016) or assume homogenous characteristics across wider areas. Sociotechnical configurations of biogas vary between locations, which influences the way biogas imaginaries are expressed. While biogas is strongly associated with regional sustainable development and ideas of a circular economy in cities like Linköping, it is seen as less desirable in a sustainability perspective in Malmö, where biogas is associated with the international natural gas pipeline from Denmark, international corporations (E.ON as the main infrastructure provider), and lack of clarity about the sourcing of feedstocks (local organic waste or Danish energy crops). The other way spatial characteristics are relevant for our study is the evocation of specific scalar relations by different imaginaries. While biogas is mostly perceived as a "regional fuel" due to its local production and distribution and can become part of regional identities (mind "the freaking biogas city" of Linköping), other biofuels such as biodiesel or ethanol are much more linked to global bioenergy markets, competition with food production and north–south relations expressing very different scalar relations in biofuel use.

In contrast, the electricity imaginary is much more aligned with a national and international scale. Electrification has historically been closely associated with nation building, industrialization, and modernization (Högselius and Kaijser 2007). It has become the epitome of the "modern infrastructure ideal" (Graham and Marvin 2001) with universal supply across the nation. Even if some EV projects are integrated in local electricity systems with a high share of renewable energy from local sources (Wentland 2016), the idea of a national supply infrastructure dominates in our interviews and documents. Moreover, EV production is driven by and associated with a highly globalized car industry.

Imaginaries of biogas and electricity are thus linked to very different imaginations of scale and spatial boundaries within which these systems operate and consequently to different interpretations of how a future transport system can be achieved and should look. This regional boundedness links the biogas imaginary to regional identities and actor constituencies while electrification of transport is associated with much broader and more homogenous powerful actor coalitions at a national and international scale. These scalar differences in how alternative transport futures are imagined and embedded also resonate with how transport system changes currently unfold—with the buildup of global strategies of international car manufacturers and efforts to create an international institutional infrastructure of

standards and coordinated regulations for electric cars versus a buildup of regional strongholds of biogas production and transport systems with rather loose national and international coordination. The relational dynamics between the two imaginaries reflect the spatial fragmentation and patchiness of biogas and its imaginaries. There is a much higher acceptance of the inevitability and desirability of an electrification of inner-city transport in Malmö, to the detriment of a forceful and continued biogas strategy, and much more hesitation in Linköping, where biogas is still seen as a key element of integrating local transport with waste management and agriculture, and electrification is only tentatively tested to keep a foot in the door of further developments. The two imaginaries and the way they relate to each other have thus evolved in different ways in these two places.

But we can also find significant differences regarding the internal contestedness and homogeneity of imaginaries of biogas and electric transport futures. Despite its close linkage to organic waste usage, visions of biogas futures cannot be dissociated from broader debates about biofuels and controversies around the use of arable land for energy instead of food production and about the ecological damage caused to biodiversity and rain forests by palm oil plantations, for example (Kuchler and Linnér 2012). Beyond these contestations of biofuel sustainability, the mobilization of biogas imaginaries is also much more fragmented across Swedish regions, as we have pointed out in the above paragraphs, and also internationally few countries have similarly close relations between biogas and transport. Due to this fragmentation, there is no coherent vision of a Swedish biogas model built on organic waste and used in transport and hardly an opportunity to align it with international discourses and visions.

In contrast, the imaginary of electrification is much more coherent. Despite the fact that sourcing of electricity is also distributed throughout the country, electricity is universally available in the same quality. Moreover, the imaginary of electrification in Sweden is closely aligned with a nonfossil energy future despite controversies about the role of nuclear energy. Furthermore, increasingly the future of transport is seen as autonomous, shared, and electric—nationally and internationally, as indicated in our analysis of policy documents and plans from international organizations such as the International Energy Agency (IEA) and Organisation for Economic Cooperation and Development (OECD), the European Commission, or reports solicited by the car industry. The discourse coalitions supporting such imaginaries of transport futures are broad and global and increasingly present these futures as almost without alternative. Still, we have identified contestations here as well, such as concerns about environmental damage

from battery production (Sovacool et al. 2019), grid capacity limitations, or questions about the availability of renewable electricity as demand grows quickly. Nevertheless, the overall imaginary of electrification of the transport fleet as contributing to a more modern and climate-friendly future prevails from the regional to global level and is linked to overall visions of modernity, innovativeness, and the use of advanced technologies. The internal contestedness and fragmentation of the biogas imaginary makes it much more difficult to present it as a desirable and universal future of transport in relation to a much less contested future of electrification. Because of the discursive dominance of electricity imaginaries, biogas futures are imagined in a much more defensive and limited way, as we have seen in local discourses and national policy statements, as a complementary solution to electric transport in certain niches (e.g., rural areas with insufficient charging infrastructure or certain regional "pockets") or as an intermediary energy carrier until a full-scale supply of electric transport is achieved. At the same time, a desirable biofuel future is conjured up by many interviewees without global (and potentially unsustainable) sourcing of biofuels, such as palm oil or ethanol, thereby further limiting its "imaginability" as a full-scale alternative to electrification.

A further dimension we have emphasized in our analysis is the importance of materiality for the structure, development, and stabilization of imaginaries. As we have argued, imaginaries can be best understood as being part of and deeply entangled in socio-material assemblages of biogas or electric transport. As a result, material properties and affordances of these two transport technologies play an important role in the constitution of these imaginaries, though we must be aware that these affordances may be only temporarily stable achievements and are not fixed over space and time. This connects to our first point about geographical scale, since the material properties of biogas and electricity can contribute to the boundedness of their respective sociotechnical configurations and their imaginaries. Properties of biogas—such as the difficulties and costs to transport it over longer distances and limits to feedstock availability—contribute to regionally bounded systems. The limited availability of biogas also lends itself more easily to imaginaries of transport futures that build on a variety of low-carbon fuels and where fuel supply is essentially limited, a feature which is salient not only in interviews in the "biogas city" of Linköping but also in the recent government report on biogas (Westlund 2019). Electricity, at least in its current, historically grown form, has infrastructural properties that make it easily available across the country and supply limitations are not perceived as an issue. Moreover, regional biogas systems are also

embedded in different ways in local socio-material contexts and linked to other infrastructures, such as the waste collection and organic agriculture infrastructures in Linköping or the gas pipeline from Denmark in the case of Malmö. These relations to other infrastructures also shape the way futures with these technologies are imagined and unfold.

However, biogas is at the same time a good example of how these purported properties may only be temporarily fixed or only stable in certain places. That links to our fourth dimension, temporality, as the increasing assent of actors or the linking to discourses and value regimes (Levy and Spicer 2013) may help imaginaries "acquire mass and solidity" (Jasanoff 2015b), though they always remain open-ended and imperfect (Willim 2017) and may again fall apart. Not far from Linköping, an EU-funded biogas liquification plant and fuel station has opened that turns biogas from a gaseous to a liquid biofuel. Liquid biogas can be transported more easily, making it marketable on larger scales. Similarly, feeding biogas into gas-pipeline infrastructures, if available, changes the limitations of biogas as a regionally bounded fuel. While these biogas-related technologies are still rarely used, they might eventually give rise to less spatially bounded socio-material assemblages of biogas and shift the terms on which biogas and electric futures are seen to compete with each other.

In a similar way, electrification has been much more unstable and contested for a long time. In their study of the cultural politics of electric car use at the end of last century, Gjoen and Hård (2002) point, for example, to the gendered image of a "second car for women" or being seen as less safe when explaining why electric cars failed to compete with combustion engines. Callon's (1986) early study on why the "engineer-sociologists" at the French state-owned electricity utility EDF failed to introduce an electric car in the late 1970s in France, despite linking it to broader visions of postindustrial cities, is a well-known example in STS. The dominance the imaginary of an electrified transport system gains over biogas-based transport, and the way it influences imaginations of a biogas-future as limited to certain local niches and complementary uses, depends a lot on the current state of these imaginaries—their legitimacy and socio-material embedding, which had varying degrees of stability over time and also now may only be a temporary achievement. Nevertheless, these current relations shape the enactment of transport futures, whether the material construction of infrastructures, the design of policies, or the support of actor constituencies. They thus impact how changes of our transport system unfold with certain alternative futures either marginalized or closed altogether.

Conclusions

In this article, we have analyzed the coexistence of multiple imaginaries, in particular of electrification and biogas use, evoking alternative transport futures that resonate with different desirable "forms of social life and social order," as Jasanoff (2015a) puts it, and with each implicated in "world-making" and enacting transport futures in the present. Such a multiplicity of imaginaries seems rather the norm than the exception in sociotechnical change, certainly in the ongoing climate-change and sustainability-related transformations of infrastructures in energy or transport.

The key point we are putting forward is that such imaginaries of biogas and electricity in transport do not evolve independently but dynamically interrelate and mutually shape each other. The way these scenarios are "co-enacted" in social practices, processes of institutionalization, or policies shapes the pathways along which the reconfiguration of the current transport system unfolds. How actors collectively make sense of the coexistence of these imaginaries—one becoming dominant and the other relegated to marginal applications or both seen as complementary in different segments of a differently imagined transport system—has consequences for the kind of future that becomes "thinkable" and desirable, the political apparatus required for their governance, the allocation of economic resources, or the materialization in infrastructures and devices. The argument we develop in this article is that the dynamics of these couplings between imaginaries are shaped by their respective socio-material, temporal, and spatial characteristics.

While electric mobility is driven by the idea of a globalized modernity and an almost deterministic understanding of technological change driven by digitalization and clean electricity, biogas-based transport unfolds around ideas of biogas production and supply closely integrated with other infrastructures of a regional circular economy of waste collection and organic agriculture. While imaginations of an electric transport future have achieved great coherence across regions and countries and are driven by the idea of an almost uniform rollout of charging infrastructures and electric cars, the imaginary of biogas-based transport is much more fragmented and incoherent. That is linked to the controversial sustainability of biofuels in general, but also to varied success in making biogas part of local imaginaries of a sustainable regional future, as we have seen in the distinct cases of Malmö and Linköping. At the same time, imagined biogas futures resonate with ideas of limitations to our mobility and the need for a variety of renewable fuel sources. Electric transport, in contrast, does not seem to

impose restrictions to ever-growing transport needs. The legitimacy imaginaries gain with various actor constituencies (their alignment with broader socio-material structures, value regimes, and policy programs) also varies over time and is linked to the historic development of these imaginaries. Only recently has electric transport become almost undisputed and gained such broad acceptance. Only a few decades ago, biofuels were less implicated in debates of "food versus fuel" or neocolonial global trade relations.

In a situation where an imaginary of electric transport is less contested and closely linked to a future of ecological modernization, whereas imaginaries of biogas use in transport are much more spatially fragmented and questioned, we see an evolving dynamic of change where imaginaries of electrification increasingly come to dominate imaginations of what a future transport system will and is desired to look like. This in consequence shapes the way current changes in the transport system are enacted through policies, infrastructure investments, and changing social practices. The biogas imaginary is defined by specific qualities, including its regional boundedness and embedding in regional development strategies, identities, and complementary infrastructures of waste and agriculture. This contributes to an uneven distribution of biogas use with regional strongholds. These strongholds remain important despite an awareness on the part of these local actors of the overall dominance of the electrification of transport and a search for complementary uses for biogas, such as in transport outside cities where it is more difficult to build an infrastructure of electrification. At the same time, the perceived advantages of biogas in many regions also strengthen national imaginaries of a future transport system with a more diverse mix of sustainable fuels. These imaginaries speak to a future where fuels like biogas may have comparative advantages for certain types of transport and certain parts of the country, while at the same time drawing attention to discourses about the limitedness of fuel supply and restraints to a growing demand for mobility. How futures of electrification are imagined across regions and at the national level is thus not independent from how biogas futures are imagined and vice versa. For which kind of uses and with which spatial distribution futures of electrification are enacted in the present depends on the relative strengths of imaginaries of a biogas future along different dimensions. The histories and characteristics of both imaginaries of electrification and biogas are thus intertwined and mutually shape both how imagined transport futures evolve and change and how the actions are formed through which transport systems are reconfigured in the present.

What we are proposing in this article is that we often deal with a multiplicity of alternative imaginaries of sociotechnical futures. Analyzing the evolution and embedding of sociotechnical imaginaries requires attention to the interrelation and interdependence of these alternatives. The dynamics of this interrelation cannot be dissociated from the social, material, and spatial relations these multiple imaginaries are part of. Conceptually, such tensions and dynamic interrelations between different sociotechnical imaginaries need to be taken into account to gain a better understanding of the role of imaginaries in world-making and in driving processes of sociotechnical change.

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