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Infrastructures, Lock-in, and Sustainable Urban Development – The Case of Waste Incineration in the Göteborg Metropolitan Areas

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Working Paper

Infrastructures, Lock-in, and Sustainable Urban Development – The Case of Waste Incineration in the Göteborg Metropolitan Area

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Abstract

This article explains how infrastructures with a sustainability record may evolve over time into a lock-in that slows the emergence of more sustainable urban infrastructures. A study of waste incineration in the Göteborg Metropolitan Area, Sweden, serves as an illustrative case. Taking leads from Unruh (2000; 2002), four rationales of lock-in are identified in the case: institutional, technical, cultural, and material. The article describes how these rationales, one by one and in collaboration, lock-in waste handling in the Göteborg Metropolitan Area to incineration. The article also suggests that these four rationales could serve as a program to unlock urban infrastructures. Asking the question "Are we in a lock-in?" is featured as a practical starting point for planning changes in urban infrastructure governance that contribute to sustainability.

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1. Introduction

Urban infrastructures are socio-technological systems that enable and regulate the efficient production, distribution, and consumption of environmentally relevant flows such as energy, water, materials, and services such as transportation (van Vliet, 2011). Therefore, such infrastructures are legitimately expected to play a key role in the urgently needed evolution of cities toward more sustainability (Peer Review Panel, 2010).

Concerned with how infrastructures actually contribute to urban sustainability, this paper examines the case of waste incineration in the Göteborg Metropolitan Area, Sweden (hereafter Göteborg): an infrastructure that has long been considered as serving a sustainable urban development but that, due to changes in conditions and demands, has started to be considered as delivering less than optimal solutions. Our contention is that, already in place and well maintained, incineration in Göteborg stands for a techno-institutional order that tends to get in the way of innovation and prevents alternative infrastructural solutions from emerging. In Unruh's (2000, 2002; Unruh & Carrillo-Hermosilla, 2006) terms, incineration is a lock-in that wedges the waste management in Göteborg to the next lowest step of the European Waste Hierarchy and slows the evolution of Göteborg and its region toward increased urban sustainability.

This paper builds on earlier research on lock-in and shows the theoretical and practical relevance of understanding urban infrastructure lock-in (or locking-in if one refers to the process that leads to a lock-in) for the planning and governance of cities towards sustainability. The lock-in of waste incineration in Göteborg is found to follow four rationales: institutional, technical, cultural, and material. We analyze each of these rationales, and show how they interact to effectively lock-in waste management in Göteborg to incineration. We show also how these four rationales can serve as a general heuristic to see if an infrastructure lock-in is involved, and, correspondingly, to look for ways to unlock infrastructures.

2. Understanding lock-in

Unruh (2000, 2002) has brought to the fore the notion of lock-in within the context of energy policy. He coined the notion of carbon lock-in to describe how technological, political, and social forces co-build a techno-institutional complex that prevents the diffusion of carbon-saving technologies.

Unruh's analysis is a reminder that technological systems do not exist in a social vacuum. They are embedded in coalitions of industry networks, together with private and public institutions such as trade-unions, trade-associations, or governmental agencies. These coalitions effectively lock-in producers, users, and regulators in dynamic webs of technologies, legislation, standards, physical infrastructures, politics, and cultural norms, inclusive of institutionalized rules-of-thumb.

The notion of lock-in originates from historical studies of science and technology. Hughes's (1983) study of the electrification of Berlin, Chicago, London, and California is a landmark illustration of the embeddedness (Granovetter, 1985) of the development of technological systems in local history, geography, and political culture. Hughes shows that technological systems follow different development styles that fit the idiosyncrasies of the time and place of their development rather than any technology-specific determinism. Likewise, Cowan (1990) explains how national security considerations gave a first mover's advantage to the potentially inferior light water nuclear power technology so that it could entrench itself in the market for power reactors and dominate the potentially superior heavy water technology. Both these studies illustrate how history keeps re-surfacing in present technology. On this account, lock-in draws even on the insight gained in science and technology studies that technological systems are neither purely social nor purely technical, but semiotico-material arrangements (Callon, 1986). These arrangements are more or less stabilized and therefore more or less stable, depending on the relationships that exist between the human and non-human actors that compose the system (e.g., Latour, 1996).

The notion of lock-in also originates from economic studies of the diffusion of technological innovation. For Arthur (1989), technological lock-ins are the logical consequence of technologies that, if adopted, generate increasing returns. The more these technologies are adopted, the more people gain experience with them, and the more these technologies are improved. Increasing returns to adoption generate positive network externalities that have the capacity to transform small initial advantages into positions of dominance from which competing technologies can be locked-out. The notion of path-dependence (e.g., Liebowitz & Margolis, 1995; Schreyögg & Sydow, 2010) is close to the notion of lock-in. Both notions underscore that today's solutions are constrained by yesterday's choices, even if these choices have lost their relevance and even if new alternatives have emerged that are more efficient and effective than the solutions that currently dominate. However, whereas path-dependence focuses on the constraints that the past puts on present decisions, lock-in describes a current state of things. And Grabher (1993) identifies three types of lock-in: functional (e.g., through joint-investments or personal ties), cognitive (e.g., because of common ways of interpreting or envisioning things), and political (e.g., through professional associations or coalitions of industrialists and politicians).

It is not easy to break a lock-in. The coalitions that benefit from it are likely to resist any change; it is difficult to challenge established standards, and few wish to abandon the comfort of increasing returns. Yet, escaping lock-ins is possible. Cowan and Hultén (1996) suggest that just like the process of locking-in can start with a small historical event or a sequence of events, possibilities for unlocking technologies can emerge from any combination of the following: a crisis in the existing technology; regulation; technological breakthrough producing a (real or imagined) cost breakthrough; changes in tastes; niche markets; or scientific results. Taking as an example the defeat of electrical vehicles to gasoline cars in the early years of the 20^{th} century, they note that a defeated technology can reappear more than a century later when conditions have changed. And D'Costa (2002) shows that market diversification, in particular, efforts to develop the domestic market, are ways to break the lock-in of the Indian software industry in low, value-added activities. More generally, Unruh and Carrillo-Hermosilla explain (2006), un-locking technology systems requires a combination of systematic efforts to promote alternatives, a critical mass or social and political recognition of a need for social action, and a focusing event that acts as a catalyst for concerns and initiatives. However, the more globalized a lock-in, the more difficult it is to dismantle it.

These difficulties to escape from a lock-in present challenges for city governance authorities. Responsible for providing day-to-day urban services and often the owners of the infrastructures that provide these services, city governance authorities are also facing increasing demands to develop the city toward more sustainability. And such demands often require confronting existing sustainability lock-ins.

Breaking the lock-in of technology systems and infrastructures is indeed featured as central for achieving more sustainable urban transformations (Coutard, 1999). Some researchers have put forward strong demands for public policies of research and development and publicly-funded projects that counteract lock-ins (e.g., Hekkert, van Giessel, Ros, Wietschel, & Meeus, 2005). Others show that public authorities with foresight can engage in coordinating, rather than corrective, activities and set up voluntary environmental agreements that have the potential to introduce discontinuity into a techno-institutional lock-in (Könnölä, Unruh, & Carrillo-Hermosilla, 2006). Yet others observe that public sector initiatives can invent new coordinating linkages between users (Yarime, 2009). This proves that it is possible to escape a lock-in and voice innovative infrastructural solutions, even if they are within clear limits when it comes to outcomes. The case of waste management in Göteborg shows how narrow these limits can be and how they can be challenged.

3. Method

This article is based on an explanatory case study (Yin, 1994) of the waste incineration in Göteborg. In designing the study, we first took leads from Unruh's Unruh's (2000, 2002) thesis that technological, political, and social forces create a carbon lock-in of energy systems and prevent the diffusion of carbon-saving technologies as preliminary categories for data collection and data analysis. When coding and categorizing the data (Strauss & Corbin, 1990), we have systematically probed whether Göteborg's waste management system could be considered as a lock-in according to Unruh's definition, and if this is the case, what could have created and could maintain this lock-in.

During the coding work, the three forces identified by Unruh (2000) (technological, institutional, and social) that we used to organize our analysis evolved into four lock-in rationales: institutional, technical, cultural, and material – the term rationale being intended to render the fact that we are speaking of logics or rationalities rather than mechanical forces. And we found that these four rationales are not only showing that incineration in Göteborg is a case of lock-in. They also explain why this is the case.

Our research strategy has been pragmatic in the sense that we have combined methods (Silverman, 1993) with the aim of being able to understand and render the techno-institutional richness of waste incineration in Göteborg. It is also pragmatic in the sense that it is neither purely inductive nor deductive, but follows patterns of creative abduction (Schurz, 2008). Inspired by Strauss and Corbin (1990), our collection, coding, and categorizing of data has involved back-and-forth moves between sorting, coding, probing the data, and collecting new data until we could reconstruct the multi-layered historical developments with the present state of waste governance in Göteborg.

Data was generated from 20 face-to-face open interviews (Kvale, 1996; Silverman, 1993). We met with officials in the Swedish Environmental Protection Agency (*Naturvårdsverket*), politicians and officials of the City of Göteborg (*Göteborg Stad*), officials of the Göteborg Region Association of Local Authorities (*Göteborgsregionens kommunalförbund*), and managers and waste management workers at Renova AB, the waste management company that the municipality of Göteborg and ten other municipalities in the metropolitan area co-own to handle waste within their jurisdiction. The interviews lasted from 45 to 90 minutes; they were recorded and transcribed verbatim for analysis.

Data was also generated from A2020, which is the waste plan for the Göteborg Region Association of Local Authorities (Göteborgsregionens kommunalförbund, 2010), and diverse informational materials from brochures, reports, and Websites provided by Renova AB and the owning municipalities. Finally, data came from two observations (Czarniawska, 2007) made by two of us: (1) a participative study-visit at the Renova incineration facility of Sävenäs and (2) a tour of the route of waste through the waste chain, from household to the end stations (landfill and incineration plant), on the side of Renova employees. Conversations held throughout the observations were recorded, and when recording was not possible, hand-written notes were taken. In addition to all of the above data collection processes, one of us has brought into this study comprehensive data about waste management in Sweden, in general, and municipally-owned waste companies, in particular, that was generated for other related studies.

Data was coded and categorized using the qualitative data analysis software NVivo. Interview transcripts, official documents, minutes of meetings, observation recordings, and field-notes have been used in a complementary and non-hierarchical manner.

4. Waste governance in Göteborg

The case of waste incineration in Göteborg serves as an illustration of how and why an infrastructure that provides services that have long been deemed as satisfying can inhibit the development of innovative, alternative infrastructural solutions. To explain why, we first describe the key traits of Swedish waste governance. Then, we describe the organization of waste management in Göteborg.

4.1 Swedish waste governance

Formally, Swedish waste governance is organized as follows. A privately-owned system of extended producer responsibilities (EPR) answers for the collection and processing of specific waste streams such as packaging, end-of life vehicles, electrical and electronic equipment, or batteries. Municipalities have the responsibility for the collection and processing of the household waste that is not encompassed by the EPR system. And the collection and processing of industrial and hazardous waste from industries are deregulated, market-based activities (Avfall Sverige, 2011).

Municipalities can handle their responsibility for household waste in three different ways: through municipal departments, municipally-owned waste management companies, or public procurements. And municipalities tend to proceed in different ways for the different stages of waste management: first the collection and then the treatment of waste. Three out of four have chosen public procurement to organize the collection of waste from households, inclusive of transfer and transport. But nearly all municipalities have chosen to answer for the treatment of waste (e.g., storage, segregation, incineration, composting, production of biogas, material recovery and recycling, disposal at landfills), primarily through municipally-owned waste management companies (Avfall Sverige, 2011).

Municipally-owned waste management companies thus play a pivotal role for Swedish waste governance: they enjoy a monopoly on household waste within the jurisdiction of their owner or owners, and can compete with privately-owned companies or other municipally-owned waste management companies for all other waste. Municipal waste companies can even import waste. However, a series of judgments by the European Court of Justice, followed by a recent intervention of the European Commission to the Swedish government have imposed limits on how much turnover municipally-owned waste companies can make with others than their owners (Corvellec, Bramryd, & Hultman, 2012).

Some key figures will define the contour of Swedish waste management. In 2010, inhabitants in Sweden produced an average of 463 kg of household waste per person, down from 513 kg in 2007. Incineration is the most common treatment method (49%) for household waste, followed by material recycling (36%) and biological treatment (14%); landfills receive only 1% of household waste (Avfall Sverige, 2011)[1].

The predominance of incineration as a waste treatment technique is largely due to the historical fact that Swedish municipalities have long been answering for both waste management and district heating systems, and that they have developed these two infrastructure systems in parallel, in particular during the post WW2 urban development and after the 1973 and 1978 rises in oil prices. Interlocking waste management with district heating systems makes it possible to recover two to three times more energy from waste than if one only retrieves electricity from waste. District heating is today the most common source of energy used for heating and hot water in dwellings and non-residential premises in Sweden (Energimyndigheten, 2011), and waste accounts for 16% of the fuel used for district heating (Svensk Fjärvärme, 2012). Waste is a well-established alternative fuel in Swedish cities, and waste incinerators have become, accordingly, stabilized infrastructures, interlinked and co-dependent with other critical urban infrastructures such as district heating or power production.

4.2 Waste Management in Göteborg Metropolitan Area

One of the 31 Swedish cities where energy is recovered from waste is the Metropolitan Area of Göteborg with a total population of over 920,000 peoples. The management of solid household waste in the area is provided by the municipal company Renova AB, and it is co-owned by eleven municipalities in the Göteborg area. The rationale behind this co-ownership was a mutually felt need for cooperation to promote a sustainable management of waste, encourage growth, and join resources to finance a capital hungry infrastructure (interview). Renova's operations include collection services for housing companies, (collection is still the largest income for the company), waste incineration with energy recovery (the second largest source of income), handling of hazardous waste, waste sorting, composting, soil decontamination, landfill deposition, and transshipment centers for waste transportation.

Incineration with energy recovery is the key waste handling process in Göteborg and this is done in the Renova-owned Sävenäs combined heat and power (CHP) incineration plant. The plant has existed for more than 40 years and is licensed to receive 550,000 tons of waste per year from households and industry.

In 2010, its four boiler lines have extracted 220,927 MWh of electricity and 1,440,620 MWh of district heating out of 539,118 tons of waste. This production corresponds to the annual electricity consumption of ca. 110,000 apartments, or ca. 5% of the electricity consumed in Göteborg, and as much as ca. 30% of Göteborg's needs in district heating (Renova, 2011a, b). Sävenäs is certainly a major element of the Metropolitan Area's energy production system.

The history of the Sävenäs incineration plant is inseparable from the history of Göteborg Energi, the municipally-owned company that delivers district heating to the local community. Göteborg Energi's district heating is 1,000 km long. It provides heating to more than 90% of all apartment blocks in Göteborg and approximately 9,000 single-family houses (Göteborg Energi AB, n.a.-a). Waste heat accounts for 86% of the fuel mix for district heat production (Göteborg Energi AB, n.a.-b). The Sävenäs plant is also pivotal to the policy of the Göteborg Metropolitan Area to reduce their CO2 emissions. Renova (Renova, 2011a, b) underscores that Sävenäs produces energy for an equivalent of 175,000 m^3 of oil or 160 million m^3 of natural gas. Sävenäs also plays a key role in Renova's efforts at minimizing the amount of waste sent to landfill. Such figures are pivotal to the image of incineration and Sävenäs as an environmentally friendly infrastructure.

Our respondents depict the Sävenäs incineration plant as being at the forefront in processing waste into energy. They feature the plant as functioning in the most possibly effective and environmentally friendly way: recovering the highest rates of energy from each ton of waste with the least emissions to the environment. The fact is that Sävenäs has been singled out as a best practice case for the successful transformation of waste into clean energy (electricity and district heating) by the Cities for Climate Change of the Clinton Foundation (C40 Cities & Clinton Climate Initiative, 2010). The foundation underscores that "Gothenburg's system of incinerating waste to make electricity and heat is highly efficient," and that "[b]enchmarked against other European countries, the system in Gothenburg compares very favourably – around 3.3 MWh per ton are generated for heating and electricity."

5. Rationales of lock-in

Despite the fact that Göteborg's incineration-based waste management system is celebrated internationally, its legitimacy may be at stake. Convergent calls for alternative waste management solutions put waste governance authorities in front of a concrete need to develop new waste management solutions. But the performance of the current system stands in the way of bringing forth innovative alternatives: the existing management system is locked-in to incineration.

In the present section we describe the rationales of this lock-in. Four rationales are presented: institutional, technical, cultural, and material. Together, these entwined rationales explain the difficulties that exist to challenge incineration in Göteborg.

5.1. Institutional rationale of lock-in

This rationale has a legal and a political dimension. Following the EU directive on landfills (European Council, 1999/31/EC), the Swedish legislation introduced a ban on landfill of sorted burnable waste in 2002 and of organic waste in 2005 (SFS, 2001:512). This legislation has clearly contributed to strengthen the strategic role of the Sävenäs incineration plant and institutionalize waste incineration in Göteborg and its region.

The reduced access to landfills created a need for alternative ways of processing waste. Incineration was logically featured as the most sustainable solution to this need as the Sävenäs plant presented the double advantage of existing already and of being expandable. Indeed, when public officers working for Renova were asked about the impacts on their activities of the introduction in the 2000s of the European Waste Hierarchy model (Hultman & Corvellec, Forthcoming), they answered that Renova was already on the track since waste incineration has been long established in the metropolitan area:

> We who work with waste, one could say we have been thinking in terms of the waste hierarchy since the early 90s … so for us, this waste directive was nothing new. We had long been thinking like that. (Interview Renova manager)

However, a more recent EU directive (European Commission 2008/98/EC) questions the legitimacy of waste incineration infrastructures and practices. Incineration with energy recovery is still placed ahead of sending waste to landfills; but it is ranked behind reuse, recycling, and prevention. Accordingly, Sweden's recently approved national waste plan (Naturvårdverket, 2012) asserts a need for initiatives that improve the resource efficiency of the current waste governance. The new national waste plan insists more than its predecessors on the need to reduce the quantity and dangerousness of waste by efforts directed at the prevention of waste. For example, concerning food waste, the Swedish government has set a new interim goal for food waste management in April 2012: by 2018, food waste from households, institutional kitchens, shops and restaurants shall be separated and processed in such a way that at least 50 percent of nutrients and 40 percent of energy shall be taken care of (Regeringskansliet, 2012). The Gothenburg Region Waste Plan (2012) echoes these targets and commits to reduce food waste up to 50% by 2020. Waste decision makers are pressured to give room to other waste handling methods than incineration, for example, waste prevention or the production of biogas.

Listening to this pressure and the demand from local politicians, the management of Renova together with Göteborg Energi studied the possibility of transforming food waste into biogas as an alternative to composting or incineration. The construction of a waste to biogas plant was rejected in 2010, though. According to our interviewees, arguments were brought forward that one could not collect enough food waste, reach enough profitability, and be certain that municipalities would continue to enjoy a monopoly on household waste in the future. Instead, a decision was made to build a pre-treatment plant that would open in 2012 to produce slurry that biogas-plants elsewhere would transform into biogas (Renova, n.a.).

This half step towards the production of biogas illustrates the reluctance there exists among the majority of decision makers in Göteborg to frontally challenge the political lock-in (Grabher, 1993) around the present incineration-based waste management system and the Sävenäs plant. Despite a clear positioning of European and national authorities in favor of a long-term evolution of waste handling beyond incineration, local actors perceive this legal and political framework as unstable. In particular they wonder whether the municipal monopoly on household waste will continue or not. Consequently, they are disinclined to introduce radical changes. They fall back on wary choices (non-choices for some). And they make rather conservative decisions, well anchored in existing legislation, that lock-in waste to incineration infrastructures and practices.

5.2. Technical rationale of lock-in

From the point of view of economic technique, the construction of the Sävenäs plant in the 1970's was made possible by the characteristic financial strength of Swedish municipalities, the historical Swedish tradition of municipal collaboration (Larsson & Bäck, 2008), and post-war Sweden's confidence in public welfare policies. But an investment of this size also prompted a long-term demand for economic returns that locked-in the waste management system in Göteborg to high-volume delivery of energy.

Our interviewees explain that the Sävenäs waste incineration plant stood for a reasonable way of drawing economic advantages from the metropolitan area's regularly rising waste volumes. Waste handling evolved in the 1970s from a concern for securing public health and mitigating environmental risks to a concern for producing energy and contributing to regional development. The municipal monopoly on waste (later reduced to household waste) secured the company's access to a steadily growing supply of waste, and the inter-locking of waste incineration to district heating created a stable outlet for Sävenäs' energy production:

> It's misleading to talk about waste incineration without mentioning district heating … Waste incineration is cheap to run; however, the initial investment is enormous. It requires a stable company that invests in it, how shall I put it, with a steady purpose over a long period of time … I used to say that the biggest investment in Göteborg we cannot see: it is under our feet. (Interview, Renova manager; "under our feet" refers to the network of district heating installations that are buried under the ground of the city)

This view was supported by the good economic results of the Sävenäs plant. It was also supported by a systematic increase in waste incineration expertise that brought Sävenäs to the forefront of technological and environmental developments, keeping at bay eventual criticisms against incineration. Economic rationality concurred with technical prowess to make incineration essential to waste management in Göteborg. And this essential character of incineration made alternative waste treatment methods, such as biogas extraction, less interesting. Alternative treatment methods were simply not deemed to be an economically sound way to spend tax money – at least before one had recovered the massive investments made in Sävenäs.

Efforts at challenging incineration and advocating alternative waste handling methods were met with difficulties. As an example, around 2005 and during the following years, an opportunity was turned down to unlock the local treatment of waste from incineration. After some years of preliminary skirmishing in the city council, a decision was made in the mid 2000s to add a fourth boiler line to the Sävenäs plant (Göteborg Stad Kommunfullmäktige, 2007). This further commitment to incineration was controversial, though. The Green Party (*Miljöpartiet de gröna*) opposed it (Göteborg Stad Kommunfullmäktige, 2007), arguing that more innovative and sustainable alternatives such as biogas, recycling, or waste prevention should have been explored instead, but this opposition was to no avail. This fourth boiler was put into use in 2009. Eventually, a reduction of the amount of waste produced in 2008 showed that this fourth boiler had brought with it an overcapacity of incineration in the region. To compensate for this local shortage of waste, Renova has to take in waste from Norway and other Swedish municipalities, an illustration of the dependence of Renova on high volumes of waste, even on a growth of waste production

As one of the politicians who sat on Renova's board underscores, board members are highly dependent on the company's managers to inform them, and they find it difficult to argue against the managers about technicalities:

> We [The Green Party] did not want the fourth boiler, and we told them [Renova]: no, do not build it. Let's decrease the amount of waste produced instead, and [do] this with the biogas and everything. I thought they listened but it was like it was already decided. They returned with figures and calculations and the politicians accepted their arguments. (Interview, politician)

The technological component of incineration tends to keep non-experts, even the politicians who are formally in charge of governing the company, away from the decision-making processes that determine the development of the infrastructure. Renova is a municipally owned company, but it is in practice difficult for the politicians in charge to govern such a large and complex technological infrastructure. Inversely, managers underscore that the board should come with coherent demands. They consider that if the board wants the company to invest in biogas, it should also acknowledge that developing the production of biogas might entail a decrease in profitability from the current levels and, therefore lower their demands for economic returns that it imposes on the company. In the managers' view, instead of complaining that the company keeps subordinating the environment to profitability, the board should create economic conditions that make it possible for the company to engage in a biogas production strategy. Difficulties for board members and managers to come to a practical agreement about how to articulate economy and ecology bring forth a stalemate that benefits the solution in place more than alternative waste handling solutions.

5.3 Cultural rationale of lock-in

Renova's accumulated expertise in incineration technology has participated decisively in establishing a culture-bound cognitive lock-in (Grabher, 1993) to a common understanding of the benefits of incineration for Göteborg. With its high-efficiency filters and significant production of energy, Sävenäs stands in the collective imagination within the Metropolitan Area as a success story of profitable and sustainable waste management. Through the years, the incineration technology and infrastructure has been developed and improved until the Sävenäs plant is considered one of the best in the world, and has also been acknowledged as such (C40 cities & Clinton Climate Initiative, 2010; see also section 4.2).

> That Denmark and Sweden are the best [at incineration] in Europe is simple.[2] In Western Europe, they had gas deposits and have built up gas networks. In Denmark and Sweden we chose district heating early. It means that … the one who produces hot water has good opportunities to find on outlet for heat energy. The one who has not invested in district heating does not have any use for a plant like [Sävenäs]. (Interview, Renova manager)

The story of incineration as a successful way to treat waste has locked-in public support around the notion that incineration is the most efficient, profitable, and environmentally sustainable way to process waste. The Sävenäs waste incineration plant champions the modern ideal of a city where economic growth is conciliated with a sustainable livelihood. Local media and our interviewees have a vivid memory of a past when waste management under-capacity created a chaotic waste crisis. In light of this past, waste incineration appears as a legitimate way to treat waste since it has successfully accompanied the economic growth of the city. Incineration is held to be a pragmatic solution to the waste issue (i.e., Sommestad 2009).

Waste incineration is a solution that internationally has given rise to criticism but that is not meeting as many public objections in Sweden as it does in, for example, France (Rocher, 2008) or Ireland (Davies, 2006). Instead, because it reduces the volume of waste sent to landfills, incineration is held as a pivotal ingredient of the societal narrative that equals good waste management with less landfilling (Corvellec & Hultman, 2012). In addition to that, since Renova produces a consequential share of the energy that the Metropolitan Area needs, it is difficult for anyone to disrupt the time-honored narrative that waste-to-energy is best, and Renova does it best. Over the years, the successes of incineration have brought a cognitive and cultural reluctance to abandon a solution that has served the city well for decades.

5.4 Material rationale of lock-in

Finally, the material dimension of the Sävenäs plant makes this, as other physical infrastructures, difficult to change. Sävenäs is where the routes of waste collection meet the pipes of the central heating system. Renova's boilers are the hub of a fine grained socio-physical network that connects all kinds of garbage receptacles to a myriad of radiators and warm water cranes all over the Region, inclusive of the behaviors attached to these. Any major change brought to Sävenäs would require a radical re-design of this network.

Picture 1: The Sävenäs combined heat and power incineration plant to the right. To the left, the highway leading into central Göteborg; note the sign (close to the truck) welcoming travellers to Göteborg. In the center of the picture, the railroad track approaching the Göteborg central station
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An incineration plant is a large installation that takes up considerable space. Erected close to the city center, the Sävenäs plant is highly visible from trains to and from Göteborg's main central station and from the highway that leads the traffic into the city. Its massive presence is a constant reminder that incineration is the main waste treatment solution that is used in Göteborg (see picture 1). Its physical presence stands for the trust that the city has put in incineration. The Sävenäs plant participates thereby in defining the place specificity of the Göteborgian urban space. It is among that which shapes the image of the city (Lynch, 1960). And this role of urban landmark strengthens the position of incineration in the Metropolitan Area. In particular, it suggests that any technology that would replace incineration would not only have to handle waste with technical efficiency and environmental effectiveness; it would also have to compensate for the spatial void that decommissioning the Sävenäs plant would involve. The materiality of the plant inscribes Sävenäs in the physical and imaginary fabric of the City.

5.5. Locking-in waste incineration in Göteborg

The case of waste incineration in Göteborg corroborates Unruh's (2002, 2002) thesis that a convergence of forces, relabeled here rationales, can create a lock-in that prevents the diffusion of waste management practices that are considered to be more sustainable, for example waste-to-biogas production or waste prevention measures (Naturvårdverket, 2012).

Today's waste management system in the city's metropolitan area is an inheritance of political choices that originated in other contexts and for other purposes, namely a waste disposal crisis leading to determined plans to reduce the amount of waste sent to landfills, and a series of unprecedented rises in oil prices in the 1970s that made it economically interesting to produce energy from waste for the newly developed district heating systems. These choices have been supported by a systematic development of technological competence and massive economic and symbolic investments in incineration.

The reliance of Göteborg on incineration is embedded in a web that stabilizes the existing techno-institutional order and hampers the development of an alternative waste policy. This web brings together disparate nods: legal texts such as the Environment Code (SFS, 1998:808) and the Waste ordinance (SFS, 2001:1063); physical facilities such as the Sävenäs combined heat and power incineration plant that physically connects the waste handling and district heating systems; and institutional arrangements such as the long-term energy delivery contracts passed by Renova with Göteborg Energi.

A majority of urban governance decision makers have deemed over the years that incineration provides returns that are satisfying, both in economic and environmental terms, and fit the idiosyncrasies of the metropolitan area. Doing something else is perceived as taking a risk, and, as a Renova representative stated, it takes some courage to take such a risk:

> When you are good at what you do, and famous for it [implicitly: as Göteborg is on incineration, our note], to start doing something else that you might not be so good at, or that will cost a lot of money – who will take that risk? It takes brave politicians that are prepared to take that risk. (Interview, Renova manager)

And most importantly, the local population has not found any reason to challenge incineration as waste handling method. Things would be fine, except that the current waste handling system creates a lock-in to incineration that fixes Göteborg's waste management at the next lowest step of the European Waste Hierarchy.

6. Concluding discussion: Unlocking infrastructures

The case of waste incineration in Göteborg shows how an infrastructural lock-in involves different but interrelated rationales that work independently, one from the other, but can at times reinforce or weaken one another: an institutional rationale that has legal and political dimensions; a technical rationale that has technological and economic dimensions; a cultural rationale that encompasses a cognitive dimension; and a material rationale that pertains even to the spatial character of infrastructures. This could be considered as a specific result, especially in light of Hughes's (1983) demonstration that technological systems follow different development styles that fit the idiosyncrasies of the time and place of their development. But many similarities could be observed, not only with other cities that have interlocked waste incineration with district heating elsewhere in Sweden, Denmark, and Finland, but also inversely in countries such as Ireland (Davies, 2006) or France (Rocher Laurence, 2008) where they have not systematically attached incineration to the production of heat and where the technique is also intensively questioned. The four rationales that are described above are generic enough to bear some relevance even in other contexts.

In addition, these four rationales also provide some clues about how an infrastructure can be unlocked. An unlocking impetus can come from a change in legislation, such as when the EU and national legislation stress the importance of waste minimization and the superiority of biogas production over incineration (Hultman and Corvellec, forthcoming). It can come from changes in the political orientation of ruling parties or changes in the political majority that displace the order given to economic and ecologic preferences. It can come from economic changes (D'Costa, 2002) such as an increased demand for non-fossil fuels for vehicles. The unlocking impetus can also come from the need of maintenance, repair, and extension (Graham and Thrift, 2007) which creates moments of potential rupture in infrastructure lock-in. Renewals and transformations make it possible to introduce new technologies (Foxon & Pearson, 2007). As Moss observes (2011), the obsolescence of urban infrastructures has an unlocking potential "for re-thinking radically how infrastructures are planned, and what services are required so as to take greater account of today's policy objectives for environmental and climate protection" (p.28). Future needs for renewals and transformations at the Sävenäs plant will create more moments like the one when a decision had to be made whether or not to build a fourth boiler.

What an un-locking process needs to commence is a sequence of events acting as catalyst for concerns and initiatives (Cowan and Hultén, 1996; Unruh and Carrillo-Hermosilla, 2006). Such concerns and initiatives introduce new ideas, values and narratives that challenge the locked-in order. For example, the Green Party in Göteborg challenged the waste incineration coalition on several occasions during the last decade by questioning the economic rationality of investing in expensive infrastructures. Such arguments are likely to surface in future debates. And even if waste is today openly considered as a resource (Swedish Environmental Protection Agency, 2005) and thus something that should be exploited as efficiently as possible, it may only be a question of time before alternative views reach the columns of the local newspaper or the debates in City Hall, for example: that urban sustainability requires waste policies that give a priority to reducing rather than exploiting waste; that considering waste as a product on a market is not likely to induce a diminution of waste volumes; and therefore that marketization of waste presents a long-term challenge to sustainable urban transformations (Zapata and Hall 2013).

Lock-ins are matters of co-evolutions (Geels, 2005a; Geels, 2005b), and to overcome a lock-in, policy makers and city managers have to re-orient an array of interrelated factors (Könnölä, Unruh & Carrillo-Hermosilla, 2008; del Río & Unruh, 2007; Unruh & Carrillo-Hermosilla, 2006). Understanding the rationales at work in a specific lock-in and how they co-evolve is pivotal to any relevant analysis of the lock-in and any effort aimed at unlocking the infrastructure. However, of even more general relevance than understanding that different rationales are at play is understanding that the notion of infrastructure lock-in offers an analytical and practical leverage to understand and orient urban policy towards sustainability.

The policies, laws, plans, and programs that aim at unlocking infrastructure need to acknowledge the local practices and the local lock-ins that hamper sustainability. Urban policy towards sustainability also has to acknowledge how to construct legitimacy around new emerging practices, laws, and physical infrastructures. Decisions makers are invited to identify the potential that may exist in new legislation and imagine innovative ownership or collaboration patterns that create new institutional orders (March & Olsen, 1989). New economic conditions and technological advances open new market possibilities for recycled materials and products. Likewise, new views on waste (e.g., industrial ecology (Chertow, 1998), cradle to cradle (McDonough & Braungart, 2009), or peak everything (Heinberg, 2007)) challenge the existing view that waste is a valuable resource to be exploited, and suggest instead that waste is something that should not be produced (Bulkeley & Gregson, 2009). Corporations and households are developing new ways to engage with waste, for example, sophisticated practices of source separation. And these new forms of engagement offer waste management companies and public authorities opportunities for unlocking socio-technical innovations (Bulkeley & Gregson, 2009).

Path-dependence (e.g., Liebowitz & Margolis, 1995; Schreyögg & Sydow, 2010) can be terminated and lock-ins can be unlocked (Cowan & Hultén, 1996; Witt, 1997). And this brings us to what might be the core innovative potential for the notion of lock-in. Coming to an understanding that a system is locked-in is a critical step towards ridding obstacles to innovation and opening up possibilities for alternative solutions. Going systematically through all of the legal and political, technological and economic, cultural and cognitive, and spatial and material rationales described in this paper is a way to take this first step. In the end, the notion of lock-in is an invitation to critical reflection concerning the future economic, social, and environmental performances of an infrastructure. Asking the question "Are we in a lock-in?" can serve as a practical starting point for sustainable urban transformations.

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Notes

[1] These figures are to be taken with some caution since they classify bottom and fly ashes as recycled products. Ashes stand for about 30% by weight of the waste that is incinerated, and not everybody would consider them as recycled products.

[2] Not every expert today would agree with this statement, though.