Cities as Development Drivers: From Waste Problems to Energy Recovery and Climate Change Mitigation

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ABSTRACT

From the middle-ages and up until and during the 19th century most cities in Europe were filthy and smelly and presented imminent health risks to humans in terms of communicable diseases. During the 20th century sanitary installations and efficient collection systems for waste and wastewater made the urban landscape cleaner and more supportive of cities as development hubs. Waste management was an important driver in this development.

In this paper we discuss how such development management and problem solving is part of the urban order, i.e. the arena in which problems emerge, become visible, are dealt with and gets acceptable solutions. The urban order includes the physical infrastructure – streets, water supply, sewage systems, solid waste disposal, energy and transport – but also a moral and social order composed of routines, norms, rules and regulations. Good urban order comprises both private and collective action, and technical as well as institutional and organizational innovation. The urban order forms a platform for innovative problem solving and potential spill-over effects, which may stimulate further economic growth and development, not only in the specific city but also in the country as a whole. Two city cases are explored: Aalborg in Denmark and Malmö in Sweden.

From these case studies it is evident that the urban orders of both Malmö and Aalborg have been able to support quite strong systems of innovation in the “waste sector”: Problems have been spotted and monitored. Interaction between different stakeholders has supported innovation. A process of policy learning has been sustained and adequate capital investments have been made. In concrete terms the waste management systems have changed from net energy consumption and net greenhouse gas emission in the 1970′ties to now net production of energy and net reduction of greenhouse gas emission. The waste management based net reduction of greenhouse gas emission now amounts to app. 1.5 tonnes of CO2 eq. per citizen and annum in the two cities.

Not every city will be able to develop efficient systems of innovation. However, promotion of systems of innovation in cities can become much more important and successful than it is today. Going from being part of the problem to providing solutions requires political will and leadership, inspiring regulatory frameworks, realistic timetables/roadmaps, and – not least – a diverse set of stakeholders that can provide the right creative and innovative mix to make it possible.
InnovationDrivenGrowth

The modern capitalist market economy is knowledge-based and knowledge is always changing. It never rests. The mere passage of time brings about new information and experiences, which inevitably leads to revision of earlier decisions and prevents equilibrium from prevailing. The economic process is incompatible with unchanged knowledge and the economy changes constantly through the evolution of knowledge. The evidence is overwhelming that the driving force behind the increase in production and income over the past few centuries has been the advance of technical and organizational knowledge (Nelson, 2007). It is the creation of new knowledge, and the combination and recombination of different types of knowledge that result in economic growth and development. The tensions and contradictions that this often leads to, and the different reactions hereby provoked, imply that economic growth is intrinsically connected to institutional and organizational change.

Knowledge may, thus, be regarded as the most important economic resource and the basic source of development. This insight is, of course, not new at all. The knowledge-based economy has deep roots in the history of economic theory. Boulding (1981) described production as a process, controlled by knowledge, in which energy transforms materials from one state to another. He said that there are three main “factors of production”: materials, energy, and knowledge - rather than labour, capital, and land as the classical economists believed - and knowledge leads the show.

New knowledge is introduced into the economy by technical, organizational or institutional innovations. The process of economic growth is thereby driven by innovation rather than by quantitative increases in the input of capital and labour.

Except from the works of Schumpeter (1942), very little was written on innovation before the 1960s. From then on interest increased, and there is now a quickly expanding economic literature about the subject. From the 1980s a new branch of innovation theory has been developed under the name of ‘systems of innovation’ (Freeman 1987, Lundvall 1992, and Nelson 1993).

There are several different notions of systems of innovation. Some are territorially based like regional and national systems of innovation and others are based in specific types of production like sectoral and technological systems of innovation. Some approaches focus narrowly on science-based innovation but others also take a broader range of experience-based innovation into account. It is common to most approaches that the innovation performance of, for example, a national economy is seen as depending not only on the innovation capabilities of its individual firms but also on how they interact with each other as well as with the financial sector and the public sector. Furthermore, innovation is regarded as a process over time including feedbacks and diffusion, rather than as a series of isolated events at specific points of time. The most important characteristic of the process of innovation is probably that it is interactive; it is based on interactive learning resulting in new combinations of knowledge.

Cities as Milieus of Innovation

The organization in time and space of production gives importance to different kinds of geographical concentration of economic activities, particularly city regions. Cities have always been the locations of the main producers of knowledge and vehicles for economic growth and development. The performance of cities hinges on organization and institutionalization of creation and utilization of knowledge.
Cities have long been thought of as innovative centres. Giovanni Botero (1544-1617) probably first expressed this clearly. In *The Magnificence and Greatness of Cities* (originally published in Italian in 1588 and in English in 1606), he described the importance of great cities for countries and their rulers. What matters most, he said, is the city’s diversity of industry, trades and crafts and its interaction with surrounding agricultural districts. The presence of a community, which accepts and includes immigrants, has an efficient and effective justice system, schools and studies, and a physical location with access to good ports are also important. Only cities can provide the necessary environment for increasing incomes and power, he said.

More than 300 years later, Jane Jacobs (1969) used similar arguments about the importance of diversity of trades and crafts to explain how cities may stimulate innovation and economic growth.

Peter Hall (1998) takes the argument further, describing great cities in their golden ages as ‘innovative milieus’ and ‘cradles of creativity’, where artistic/cultural, technological, and organisational shifts take place. The factors that shape cultural and artistic creativity are to a large extent the same as the ones that shape technological innovation, Hall argues, and these are largely found in cities.

One way to sum this up is to say that, evidently, cities may constitute powerful systems of innovation.

**How Cities May Contribute to Sustainable Development**

The importance of variety is one of the oldest topics in the literature about innovative cities. Variety may be seen in the population’s age structure, culture, occupation, skills, competences and tastes, in the organisation of production in terms of firm size and mode of organization, in the city’s institutional variety and in the diversity of the production and supply of public as well as of private goods and services.

Variety creates the potential for innovation. Whether this potential is utilized or not depends basically on two further factors: First, it requires some kind of *proximity* between the persons and organizations that have the potential to interact and recombine different kinds of knowledge, as the costs of interaction must not be too high. The relatively short physical distances and dense communication networks of well-functioning cities sustain face-to-face as well as other types of communication, which support interactive learning and innovation. Second, realisation of the potential provided by variety requires *investments in the development of knowledge*. Knowledge may be intangible but it does not recombine without costs; innovation requires expenditures on materials, equipment, testing, training, education, and associated matters.

Economically vibrant city economies provide both demands for these kinds of investment and the resources to invest. Development has been described as the mobilization and utilization of ‘hidden, scattered and badly utilized resources’ (Hirschman 1958); cities have often been relatively good at such mobilisation and utilisation.

Big congregations of people are intrinsically complex and cities are messy and disordered places. They generate problems. Large groups of people living and working in close proximity put strains on natural resources and energy. Congestion puts transport systems under stress and the high costs of land leads to intense land utilization. Air pollution, insufficient waste treatment and high contamination levels may engender health problems. Furthermore, in cities, redistribution of income and power between persons and organizations in connection with fast growth and structural change lead to conflicts and undermines social capital. Creative periods of city development are often characterised by the recognition of such long-term problems (Hall 1998), by the development of solutions for them and by an enhanced acceptance of change.
People in cities have had to be creative in developing an ‘urban order’ as a framework for city life. The urban order can be thought of as an arena in which problems emerge and become visible in ways and places, which also includes possibilities for their solution. Urban order includes physical infrastructure but also a moral and social order backed by an institutional order composed of routines, norms, rules and regulations. The urban order must serve as a platform for solving the major environmental and social problems generated by city growth if further development is to take place. Cities may contribute to sustainable development by clearly demonstrating the problems, which need to be solved and by providing the creative environments for the solution of these problems. This is only possible, however, when cities form efficient systems of innovation.

WASTE PROBLEMS AND SUSTAINABLE CITY DEVELOPMENT

Historically we can see that when environmental and health problems have grown to critical dimensions, innovations, sometimes radical ones, in both technology and administration have emerged in cities and contributed to urban growth and further innovation in a virtuous circle (Johnson and Hansen 2007). The sewage system of ancient Rome is a well-known example. Much has also been written about how the fast population growth and the cholera epidemics in the middle of the 19th century led to the construction of sewers in many cities in Europe. In Copenhagen a sewage system was built in the 1860s, a few years after a cholera outburst had killed many thousand people. The engineering challenge of the project, the size of the investments and the conflicting interests between the citizens (who wanted the problems solved as quick as possible), ground-owners (who had to carry some of the costs and whose property rights were infringed) and farmers (who lost a valuable source of fertilizers) illustrate the difficulty of the problem and explain the delays.

In the rest of this paper we are going to illustrate, with recent examples from two Scandinavian cities, Malmö in the south of Sweden and Aalborg in northern Denmark, how innovation in waste prevention and waste management may contribute to sustainable development. These cities have been innovative in the sense that they have been able to solve concrete problems in situations characterised by technical and political uncertainty.

Waste Prevention and Waste Management as Aspects of Sustainable Development

All human activity generates waste. Cities may not generate more waste per capita than other localities with comparable income levels, but the congestion of people makes problems more visible, concentrated and harmful. It is obvious that untreated waste may cause numerous health and environmental problems and historical examples are abundant. In cities, the sustainability of such situations is often quickly drawn into doubt and search for solutions seems more necessary than in less congested surroundings. Not only have acute waste problems been solved but, in some cases, the problems have even been transformed into contributions to more sustainable development.

For example, in Malmö and Aalborg in a relatively short period of time, from the last half of 20th century to the beginning of the present century, action on waste has gone from landfill problems to energy recovery and climate mitigation.

The improvements in waste and wastewater management in both Malmö and Aalborg from 1960 to 2010 are to a considerable degree similar with regard to treatment processes, technology and time profile. An overview of the development in organic waste and wastewater management in the two cities is given in Table 1. Prior to 1960, all organic wastes were deposited in landfills, but between 1970 and 1980 both cities diverted organic waste from landfill to incineration. In Malmö heat from the incineration process was recovered while in Aalborg heat recovery was implemented later, between 1980 and 1990.
During that same period Malmö also implemented landfill gas extraction with energy recovery at its major landfill site and both cities initiated separation of yard waste for composting and land application of the compost. Between 1990 and 2005 both cities changed from producing only heat to producing both heat and electricity at their waste incineration facilities and by 2010 the energy recovery process was improved to also include additional heat production via condensation of vapour in the flue gas.

Table 1 Timeline for waste and wastewater developments in Aalborg Municipality, Denmark and in the Malmö region, Sweden. The net impact on energy production and Greenhouse Gas (GHG) emissions is shown at the bottom for six selected years (1970, 1980, 1990, 2005, and 2010), between which major changes of processes, technologies and operations were implemented.

Prior to 1960 no systematic wastewater treatment took place in either of the two cities but by 1970, Malmö had implemented biological oxygen demand (BOD) removal combined with heat and power production via anaerobic digestion of the sludge. The digested sludge was applied to farmland. Aalborg implemented BOD removal in its wastewater treatment between 1970 and 1980 and sludge digestion with heat and power recovery between 1980 and 1990. Prior to 1990 the Aalborg sludge was landfilled but after implementation of digestion, the sludge was applied to farmland. By 2005 Aalborg had changed its sludge disposition strategy from farmland application to incineration with energy recovery. In a transitional period the sludge was used as fuel in cement production. In Malmö the sludge to farmland strategy was maintained. Between 2005 and 2010 Malmö initiated separate digesting of biodegradable wastes from for instance households, restaurants and food producing industries. Integrated waste management systems have provided the conceptual approach all through.

Given the dual purpose of environmental protection and energy savings and recovery (increased consciousness since the mid 70'ties) Table 1 also shows energy balances for the systems handling organic wastes from Malmoe and Aalborg, including both heat and electricity recovery on a per person and annum basis. Additionally, with a view to the new climate change challenges, Greenhouse gas (GHG) emissions are assessed as well on the same basis. Energy figures are derived from calculations based on material and energy balances on existing waste management facilities (including wastewater treatment plants) and GHG numbers are derived from emission factor calculations using coal as the substituted energy source; cf. Poulsen and Hansen (2009).

Prior to 1980 the Aalborg organic waste and wastewater treatment system was a net GHG emitter because no energy or nutrients present in waste or wastewater were utilized while
the processing consumed energy. In Malmö the waste and wastewater management system was a net GHG saver in the same period, primarily because methane produced from landfilled waste was later extracted and utilized for energy production, and because sewage sludge was anaerobically digested with energy production. In both cities, the implementation of waste incineration with heat utilization (implemented in Malmö 1970 – 1980 and in Aalborg 1980 - 1990), further improved GHG balances. Upgrading the waste incineration process to produce both heat and power (implemented 1990 – 2005) resulted in approximately 30% increase in GHG savings. A further 25% increase in GHG savings was obtained via condensation of flue gas vapour (implemented 2005 – 2010) resulting in increased heat production from waste incineration in both cities. In Malmö diversion of part of the food waste etc. from incineration to biogas production (implemented 2005 – 2010) yielded an additional 5% increase in GHG savings.

Thus, new systems and technologies have in the period 1970-2010 continuously and significantly decreased negative environmental impacts and increased the energy returns. Cleaner cities now provide healthier and higher quality of life for citizens; improved biological and thermal treatment technologies reduce toxic emissions to soil, water and air; and the overall energy budgets for waste management improve steadily. This development was further enhanced when after 2000 the climate change issue really entered the political scene, cf. IPCC (2007), ISWA (2009) and WM&R (2009, a, b). Waste and wastewater management systems have been transformed from being net consumers of energy and net emitters of greenhouse gasses into net producers of energy and net savers of greenhouse gas emissions, cf. table 1.

The point is here that cities could be key agents and drivers in the climate change mitigation by really addressing waste management in a multi-targeted way as done in both Malmö and Aalborg. Table 2 shows how in those two medium sized cities in northern Europe the accomplished savings from improved waste management (more recycling and energy recovery) are between one and two tonnes of CO2 equivalents per capita per annum. This amounts to 10-20 % of the total annual per capita emission for an average European citizen in 2006.

<table>
<thead>
<tr>
<th>kg CO₂ eq. per person yr</th>
<th>Aalborg Municipality</th>
<th>Malmö region</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG from waste and wastewater</td>
<td>-210</td>
<td>-200</td>
</tr>
<tr>
<td>Recycling of glass, metal, paper and cardboard</td>
<td>-850</td>
<td>-1160</td>
</tr>
<tr>
<td>Biofuel from wood not used for paper prod.</td>
<td>-360</td>
<td>-380</td>
</tr>
<tr>
<td><strong>Total GHG emission reduction</strong></td>
<td><strong>-1420</strong></td>
<td><strong>-1740</strong></td>
</tr>
</tbody>
</table>

Table 2 Summary of total GHG savings in Aalborg municipality and the Malmö region in 2010, including not only wastewater and municipal organic waste management (table 1) but also recovery of glass, metals, paper & cardboard, and use of saved wood (saved due to recycling of paper & cardboard) as a bio-fuel that substitutes for use of fossil fuel (coal). Modern technology is assumed for emission factors, i.e. conservative estimates are used for CO₂ –eq. emissions. Data is from Aalborg (2010) and SYSAV (2010).

**Innovation Systems in Waste Treatment**

The problem of making city development sustainable and making cities contribute to sustainable development of regions and countries may not primarily be a question of improvements in waste management (prevention and treatment). But it is a necessary part of it and, above all, it can be used as an illustration of how cities may stimulate and
support the innovation processes, which have to have to be the core of anything bordering on sustainable development.

The improvements described above have required substantive capital investments, for example in the pipe networks for both wastewater and heat. In addition, it has also required development not only of technical knowledge as illustrated above but also organizational knowledge and new institutions. Technological, organizational, political and institutional factors have interacted in the improvement of waste management. Several types of players have been involved and the balance between them has changed.

The technical innovations in this process were developed in a close interaction between private firms, including engineering consultants, and public organizations and policy makers. Over time, the role of private firms has increased, perhaps as a reflection of an increasing need for flexibility in formulating and solving environmental problems. To keep the process going, sustained pressure from public organizations with adequate technical and political competence has been necessary. An environmental bureaucracy has developed and the environmental departments in the cities' management structures have become central players in the decision-making processes in these matters. New types of actors have emerged and strongly influenced both the technical development and the political implementation process. For example, already in 1974 nine municipalities around Malmö formed a new company (SYSAV) which runs integrated waste treatment and combined heat and power (CHP) facilities in the Malmö region. New private players have also emerged and some of them have been able to utilize the increasing focus on waste treatment for developing new technologies for the international market.

Interaction and cooperation between research institutions and the city have played an important role for the development of new knowledge and competence within waste treatment. In Sweden the Technical University of Lund has been involved in many development projects in the city of Malmö since the beginning of the 1970’s. In Denmark Aalborg University has shown how the distance between basic research in molecular biology in mixed microbial cultures and application in practice can be very short, for example in full-scale performance of biological phosphorus removal in wastewater treatment and in a wider perspective protection of resources and environment, cf. Nielsen (2010) and Vollertsen (2008).

It is important to notice that new environmental legislation and new central government bureaucracies that have developed during the last four decades, have formed an enabling framework for the innovations and investments in waste treatment in Malmö as well as in Sweden as a whole. This is also the case in Aalborg and Denmark, even if the direct cooperation with the research sector (for example Aalborg University) has developed slower than in Malmö. However, during the last 5 years the city-university interaction has increased considerably. This cooperation is focused on concrete tasks such as the development of a climate strategy for the city and optimization of district heating based on renewable energy.

Aalborg city and Aalborg University together also develop a strategy for sustainable development of the private enterprise sector, helping firms to identify environmental challenges and to develop and finance innovative solutions and introduce them to the market.

Different tools for measuring, modelling and simulating potential development scenarios and environmental impacts have been developed during the period. Mass balances, mathematical modelling, mass flow analyses, cost benefit analyses and life cycle assessments are examples of instruments developed by universities and research institutions and applied to both theoretical and practical problems, often in a project context where a city and an academic institution have worked together. Improved
predictability in development scenarios, improved interaction between stakeholders, and improved decision-making at the political level (given more factual and up-to-date information) have become concrete results of the availability of these new or significantly improved tools.

Another influential factor has been the development of new visions and long-term goals related to sustainable development. The whole process has been affected by international shifts in the visions and ambitions of environmental policies, progressing from simple ideas of pollution prevention to climate change mitigation and supported by cleaner and greener technologies and institutions. The waste hierarchy (reduce-reuse-recycle-recover) has been a strong political guide in waste planning at both national and regional levels.

The strengths of the vision affect the possibilities to implement effective policy measures. In the examples of Malmö and Aalborg it seems clear that effective local implementation building on “holistic” visions of socially and environmentally sustainable city futures have backed the development. The ability to form and adapt visions and to reach relative consensus about them is an important aspect of a city’s system of innovation. A relative political independence vis-à-vis the national government in a range of matters as for example legal power to introduce restrictions and collect fees, which is the case for example in the Nordic countries, is another critical characteristic. At the same time it is evident that changes in the legal framework at the national level have been crucially important. A set of new taxes, subsidies and direct regulations has resulted in quite strong incentives for the cities to improve waste management.

In both Malmö and Aalborg there has been a context of increasing environmental ambitions, supportive legislation and positive feed-back interaction between research institutions, waste managers of the cities, and private firms, resulting in steadily improving performance in waste treatment.

CONCLUSIONS

- Since the early 1970's a legal and regulatory framework promoting environmental protection and material resource conservation has existed and undergone continuous adjustments in both Sweden and Denmark. The European Waste Hierarchy has strongly influenced waste policies since the 1980's.

- By focusing on organics in wastes and wastewater from households it has been possible to improve the situation from net consumption to net production of energy on a per capita basis in the cities Malmoe in Sweden and Aalborg in Denmark. Simultaneously, significant environmental impact improvements have been achieved, e.g. in terms of cleaner cities, less landfilling, and discharge of only treated wastewater into the environment.

- When entering the 21’ century with demands for climate change mitigation, the two cities were well prepared and were able to prove net reduction instead of net emission of greenhouse gases from waste management, mainly as a result of energy recovery and enhanced by material recovery programmes. On an average, each citizen accomplishes a per annum reduction of 1.5 tonnes CO2-eq..

- In this paper it has been argued that cities may become important contributors to sustainable development. By upholding an urban order cities may provide an important arena for interactive learning and innovation. This in turn may help cities to develop well functioning systems of innovation that support “clean” economic growth.
The issue of waste treatment in two medium-sized Scandinavian cities has been used to illustrate these arguments. Summing up, it seems clear that the urban orders of both Malmö and Aalborg have been able to support quite strong systems of innovation in the “waste sector”: Problems have been spotted and monitored. Interaction between different stakeholders has supported innovation. A process of policy learning has been sustained and adequate capital investments have been made.

To avoid misunderstanding and exaggerated optimism it should be emphasized that not every city is able to develop efficient systems of innovation. To a large extent the innovativeness of the most dynamic cities of the world has evolved more or less spontaneously. Only to a limited degree have systems of innovation been politically designed and implemented. There is no reason to believe, however, that promotion of systems of innovation in cities cannot become much more important and successful than it is today. There is now a lively research about the structure and change of systems of innovation, and city planners in many countries are increasingly putting this issue on the agenda.

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