Towards a sustainable waste management : Habits and behaviour

Åkesson, Lynn

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Towards Sustainable Waste Management

Popular Summary Report from a Swedish EPA Research Programme

Tomas Ekvall and Sara Malmheden (Eds.)

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Foreword

This report summarizes results and conclusions of the research programme Towards Sustainable Waste Management, carried out during 2006-2012 with funding from the Swedish Environmental Protection Agency (EPA). The report is based on contributions from the researchers in the project, and has been edited by Tomas Ekvall and Sara Malmheden at IVL Swedish Environmental Research Institute, where the programme was coordinated. A large number of research groups and individual researchers contributed, among these we would like to mention the following:

- IVL Swedish Environmental Research Institute: Tomas Ekvall, Elin Eriksson, Maria Ljunggren Söderman, David Palm, Åsa Stenmarck, Jan-Olov Sundqvist, and Anna Widheden
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- University College of Gävle: Ola Eriksson
- Chalmers University of Technology: Raul Carlson and Johan Tivander

The EPA has not only sponsored us but has also been the principal beneficiary of our research. We are grateful for the open exchange of information and the close collaboration we have had with officers there: Sanna Due, Cecilia Mattsson, Katarina Schough, Catarina Östlund, and others. These contacts have played a key role in ensuring that our research is relevant and can be put to good use.

Over the years our reference group has contributed valuable comments. The group has included, among others: Per E.O. Berg, Eva Blixt, Thomas H Christensen, Patrizia Finessi, Christer Forsgren, Johan Gråberg, Thord Görling, Annika Helker Lundström, Viveke Idh, Viktoria Ingman, Gunilla Jarlbro, Lena Jarlöv, Veronica Johansson, Christer Lundgren, Per Nilzén, Karin Norberg, Katarina Pettersson, Maria Schyllander, Anne-Marie Tillman, Christina Wiklund, Weine Wiqvist, and Bengt Wånggren.

We are also grateful for the collaboration that made it possible to arrange five well-attended seminars for the waste industry during the programme. The first three were arranged by the Programme Communications Coordinator, Maria Ljunggren Söderman, with the help of IVL Kunskap. The last two were arranged with Waste Refinery and in cooperation with Congrex, Avfall Sverige – Swedish Waste Management, and the Swedish Recycling Industries' Association.

The contents of this report and other publications from the research programme are the responsibility of the researchers and do not necessarily reflect the standpoints of the Swedish EPA or the programme reference group.

Tomas Ekvall, IVL Swedish Environmental Research Institute
Programme Manager, Sustainable Waste Management

Contents

Summary

The purpose of the research program Towards Sustainable Waste Management has been to assemble, develop and evaluate ideas for policy instruments for a more sustainable waste management. The waste management should contribute to reducing the environmental impact of the society, for example through reduced waste quantities and increased recycling. It should be cost-efficient and also be accepted among the public as well as other important stakeholders.

Our aim was also to develop tools and methods to evaluate such instruments. For example we have developed a package of computer models to analyse the quantities of waste that can arise in the future (EMEC), how these different quantities might be treated (NatWaste), and how this can affect the environment (SWEA). The models also provide information about the cost of waste management and how the Swedish economy in general can be affected by the policy instruments. This package of models, together with our other models and methods, give us a unique capability for the assessment of new policy instruments and the analysis of complex questions on waste quantities and waste treatment.

Our assessments and conclusions have a broad scientific basis. We combined the three models above with other calculations and with qualitative analysis and discussions, based on research in ethnology, psychology, economics, etc. This means that we are also able to analyze issues of acceptance and discuss how information should be designed to be effective. People often like to contribute to a good environment, through source separation, etc. However, each individual has a clear limit regarding how much effort to spend. A positive attitude towards source separation does not reach far, when the sorting of a waste fraction is considered difficult. Hence, it must be easy to do the right thing.

We found that people who are not satisfied with the waste-management system are uncertain over it rather than unhappy with it. Clear information can be of great benefit, if adapted to the situation and audience, and especially when combined with other policy instruments. Besides information, we assessed fifteen other policy instruments that aim for waste prevention and increased recycling of materials:

- Raw materials tax
- Tax on hazardous substances
- Recycling certificates
- Prohibition of distribution of advertising to households that have not expressly agreed to this
- Reduced value added tax (VAT) on services
- Negative labeling of products with hazardous substances
- Requirements for companies to work on waste minimization
- Improved surveillance by authorities
- Weight-based waste-collection fee
- Environmentally differentiated waste-collection fee
- Consumer-friendly waste collection systems
- Climate Tax on incineration of waste with fossil origin
- Weight-based tax on incineration of waste
- Green electricity certificates for waste incineration
- Obligation to recycle recyclable materials

Of these, the obligation to recycle recyclables seems to provide the greatest environmental benefit. A weight-based waste fee also results in increased source separation and recycling. Raw material taxes and recycling certificates aim at stimulating or requiring a demand for recycled materials. The introduction of such instruments in a single country like Sweden has a small effect on the total recycling of the materials, partly because the supply of recycled material is insensitive to changes in the market.

Reducing VAT on services helps to shift consumption away from goods to services. This reduces the quantity of waste per consumed Euro. The quantity of paper waste in the households is reduced if the distribution of advertising is prohibited to households that have not expressly agreed to this. The waste quantity can also be reduced through demanding waste-minimization plans or similar in companies and through improved surveillance of the companies by authorities. We expect each of these instruments to affect the waste quantity with a few percent or less, but together they can still have a significant effect.

Some instruments are complementary and therefore good to combine. It is, for example, a good idea to combine the weight-based waste-collection fee with consumer-friendly collection and information, because this reduces the risk that households dispose of their waste illegally. Information can be a powerful tool if it is combined with other instruments, but isolated it is difficult to get it effective.

In Towards Sustainable Waste Management we evaluated one or two versions of each instrument. Our studies in addition gave ideas for new versions of some of the investigated instruments and also ideas for completely new instruments. A substantial tax on the use of materials could, for example, lead to increased material efficiency in industry. Support to repairing services could extend the life of certain products and thus reduce the waste quantity. Allowing temporary landfill or storage of plastic waste that cannot be recycled could reduce greenhouse gas emissions. Well established tools like deposit systems and the landfill tax could be expanded to include more products and waste fractions. Further research or investigations are needed both on these new ideas about the instruments we have studied, to determine whether – and if so, how – they are inserted into practice.

Among the instruments in place today, and also among the possible policy instruments that we have studied, there are a few that greatly affect the treatment of waste. Examples include landfill bans, the extended producer responsibility, and the obligation to recycle recyclables. However, it is more difficult to find instruments that drastically can reduce the waste quantity. This quantity seems to be decided mainly by the economic and technological development in the society, and by consumption patterns and the lifestyle of the citizens. To find policy instruments that can greatly reduce the quantity of waste we need further innovation in this area.

The results from the research program have been published in more reports, scientific articles, etc., many of them in English. Visit our website www.sustainablewaste.info for a full list of publications.

Introduction

Sustainable waste management contributes greatly to reducing society's environmental impact and resource consumption. It is reasonably cost effective and widely accepted by the general public and other key stakeholders. Swedish waste management has become much better for the environment, but recycling can be further increased and made easier. Keeping the amount of waste down is another challenge. In the research programme Towards Sustainable Waste Management we have investigated a variety of ways of preventing waste and governing the waste management system in a more sustainable direction.

Why Study Policy Instruments that Target Waste?

Waste management in Sweden has changed a lot since the early 90's. The disposal of household waste and other combustible waste in landfill sites has decreased significantly and in effect virtually disappeared. Waste incineration has increased, as has the recycling and the biological treatment of waste. Changes in waste management are largely the result of policy instruments. One example of this is the landfill ban on organic and combustible waste. Taxes are also levied on the landfilling of ashes and certain other waste flows. Producer responsibility for packaging waste, newsprint, etc. means that the recycling of these fractions has increased.

The environmental impact has been reduced due to the changes in waste management. Waste management now provides a variety of different commodities. For example, recycling leads to the production of new materials, replacing those derived from natural resources. Incineration generates heat and electricity that can replace heat and electricity fuelled by other resources. If these utilities are taken into account, as well as the fact that they can replace other forms of production, this means that waste management can actually contribute to a reduction of the environmental impact of the society!

On the other hand, waste often contains hazardous substances and care must be taken not to spread them. Furthermore, the more waste we generate, the more materials, food and other goods we have consumed. The production of these commodities typically causes more pressure on the environment than can be compensated by waste recovery. Therefore the fact that the amount of waste is on the increase poses a problem. It is not enough to treat waste satisfactorily, we must also keep the quantity of waste down – or to be more precise, use the materials and the food we produce as efficiently as possible – and in addition strive to minimize the levels of hazardous substances in the waste.

Even though the environmental impact of waste has decreased, there is considerable scope for further improvement. Figure 1 shows the potential that exists for reducing environmental impact in 2030 through more recycling. The figure shows that even if the rate of recycling has not changed at this point the waste management system will contribute, among other things, to a reduction of greenhouse gas emissions. If we can exploit the full potential for increased recycling this environmental gain will almost be tripled – in absolute figures this would mean that savings would increase from just over two million tonnes carbon dioxide to more than six million tonnes. This can be compared to Sweden's total emissions of just over 50 million tonnes carbon dioxide in 2010. The figure shows that increased recycling also leads to a reduction of other types of environmental impact.

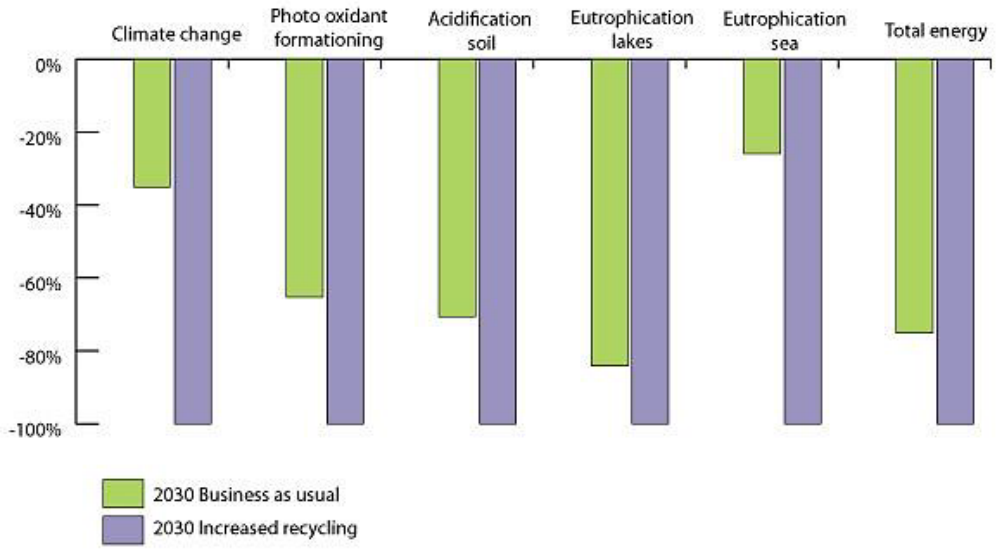


Figure 1. Even at today's recycling rate (green bars) the waste system helps reduce society's environmental impact. With a greatly increased recycling (blue bars) the environmental benefits are even greater. The bars are negative to show the reduction in environmental impact. Results are normalized to the environmental benefits of increased recycling, which means that all the blue bars show -100 per cent. Source: Ambell et al. 2010.

There are several reasons to continue developing the waste management system and policy instruments in this area. One is the need to reduce greenhouse gases and other pollutants, and here waste management can clearly make a contribution. Another is that EU requires us to strive towards waste prevention and increased recycling. The EU waste framework directive states that a waste

hierarchy should guide the waste policies of member countries. Waste prevention is the foremost and most desirable measure. Prevention is both about reducing the amount of waste generated and reducing its harmfulness. After prevention, the EU waste hierarchy lists the following steps in descending order: preparation for reuse, recycling, recovery including incineration with energy recovery, and finally disposal by, e.g., landfilling.

Several of the policy instruments available today ban or discourage landfill disposal. This is a good thing. But there are few instruments that encourage waste prevention and increased recycling, with the exception of producer responsibility for certain product groups. There is thus a need to develop instruments that will prevent waste and contribute to increasing recycling.

A more sustainable waste management is about reducing the environmental impact and resource consumption, but it also needs to be cost effective and have wide acceptance among the public and other key stakeholders.

Information, Taxes, or Bans – What Policy Instruments to Study?

In the beginning of the project we gathered together suggestions for new policy instruments. We did this by arranging several working meetings with various stakeholders and waste experts. At these meetings participants were invited to discuss and propose different policy instruments. Based on the results and earlier compilations we were able to put together a list of 55 different proposals of varying kinds: bans and regulations, taxes, information, and improved infrastructure. Subsequently we convened another working meeting, attended by representatives from various stakeholders in Sweden, to find out which of the instruments they thought merited evaluation. Based on this meeting, but also on our own assessments of what was interesting from a research point of view, we selected the following 16 policy instruments for further study (see Bisaillon et al. 2009):

- Information to consumers and companies
- Tax on natural resources
- Tax on hazardous substances
- Recycling certificates
- Bans on distributing advertising to households that have not expressly agreed to this (hereinafter referred to as "Advertising? Yes Please!")
- Reduced value added tax (VAT) on services
- Warning labels on products containing hazardous substances
- Requirements on waste minimization programmes in companies
- Improved supervision by authorities
- Weight-based waste-collection fees
- Environmentally differentiated waste-collection fees
- Consumer-friendly waste-collection systems
- Climate tax on incineration of waste of fossil origin
- Weight-based tax on incineration of waste
- Green electricity certificates for waste incineration
- Mandatory recycling of recyclable materials

Evaluating the Policy Instruments

Several of the selected instruments were evaluated in dedicated projects within the research programme. We have determined how instruments can affect the amount of waste, the economy in general, the waste disposal system, and the waste system's environmental impact. We have also assessed how the public and other stakeholders may react to the instruments. This comprehensive evaluation requires expertise in many different areas. In the research programme Towards Sustainable Waste Management (TOSUWAMA) experts on life cycle assessment (LCA) and waste management have been working together with economists, psychologists, ethnologists, engineers, and futurologists.

This means that a wide variety of evaluation methods were employed. These included both quantitative modelling and qualitative narrative analyses. A large part of the calculations were carried out utilising a suite of three linked models (see Figure 2):

- EMEC, a model of the Swedish economy, was used to analyse how policy instruments can affect economic growth, volumes of waste, etc.
- NatWaste, a technical and economic model for Swedish waste management, was used to analyse how the waste system can be managed.
- SWEA, an LCA model of the environmental impact of waste management, was used to analyse how the environmental impact may change as a result of a policy instrument.

The development of SWEA and the further development of the EMEC and NatWaste models were in itself an important part of the research. The models and methods developed by TOSUWAMA provide us with unique opportunities for further analyses of new and complex issues related to waste and waste management.

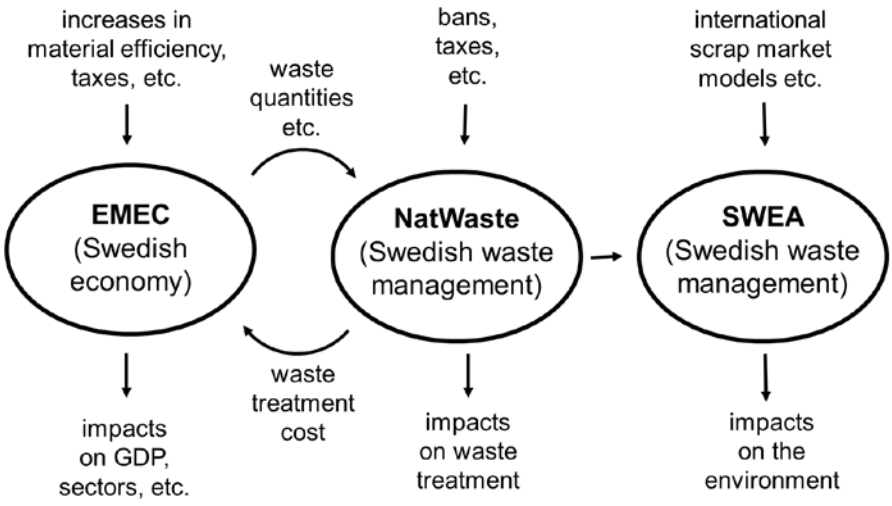


Figure 2. The TOSUWAMA research programme developed and elaborated on three computer models and linked them together in a package that helped us implement much of our calculations.

The effects an instrument has may also depend on future events. We have described five different scenarios for the development to the year 2030. They are based on different assumptions about how

much the economy is globalized, and how much it is controlled politically. The scenarios also include arguments and assumptions on economic growth, technological development, public concern for the environment and more (see Dreborg and Tyskeng 2008). We calculated and discussed the effect of different instruments in these different scenarios.

The lessons we have learned from our quantitative and qualitative analyses are summarized in the various sections of this report. The results have also been published in more detailed reports, scientific articles, etc. The most relevant are listed at the end of each section. A complete list of publications can be found at our websites: www.sustainablewaste.info and www.hallbaravfallshantering.se.

TOSUWAMA Publications (see www.sustainablewaste.info)

Bisaillon M, Finnveden G, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2009) Nya styrmedel inom avfallsområdet? TRITA-INFRA-FMS 2009:7. Royal Institute of Technology, Stockholm.

Dreborg K-H, Tyskeng S. (2008) Framtida förutsättningar för en hållbar avfallshantering – Övergripande omvärldsscenarier samt referensscenario. TRITA-INFRA-FMS 2008:6. Royal Institute of Technology, Stockholm.

Ekvall T, Björklund A, Eriksson O, Östblom G, Sjöström M, Söderman ML, Stenmarck Å, Sundqvist J-O. (2009) Modelling to assess policy instruments. Proceedings of 12th International Waste Management and Landfill Symposium, 5-9 October 2009.

Finnveden G, Bisaillon M, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2012) Developing and evaluating policy instruments for sustainable waste management. International Journal of Environment and Sustainable Development 11(1): 19-31.

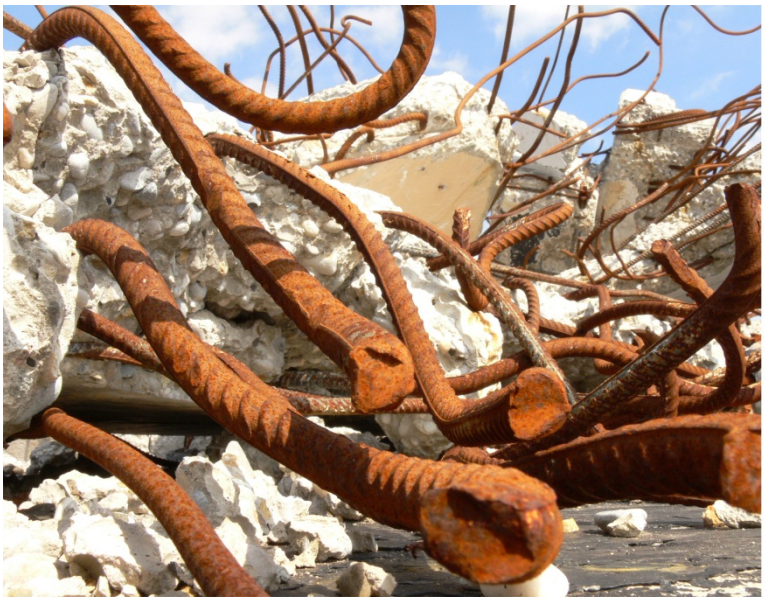
Ljunggren Söderman M, Björklund A, Ekvall T, Eriksson O, Östblom G, Sjöström M, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for assessing policy instruments for a more sustainable waste management. Proceedings of 4th International Conference on Life Cycle Management, Cape Town, 6-9 September 2009.

Ljunggren Söderman M, Björklund A, Eriksson O, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for analysing policy instruments towards a more sustainable waste management, Proceedings of SETAC Europe 19th Annual Meeting, 31 maj – 4 June 2009, Göteborg.

Ljunggren Söderman M, Björklund A, Ekvall T, Eriksson O, Forsfält, T, Stenmarck Å, Sundqvist J-O. (2011) Policy instruments for a more sustainable waste management. Proceedings of 5th International conference on Life Cycle Management, Berlin, 29-31 August 2011

Additional literature

Ambell C, Björklund A, Ljunggren Söderman M. (2010) Potential för ökad materialåtervinning av hushållsavfall och industriavfall, TRITA-INFRA-FMS 2010:4. Royal Institute of Technology, Stockholm.



The Quantity of Waste

Reducing waste is good for the environment, mainly because the need for energy and natural resources associated with the production of the materials that become waste decreases. However, it is difficult for the authorities to greatly influence the total quantity of waste. Policy instruments that make goods and materials more expensive can have some effect. The same is true for instruments that stimulate the repairing of used goods, second-hand markets and technological development. But in the end the waste quantity is determined more by economic and technological breakthroughs, consumption patterns and lifestyle choices.

Current Waste Quantities

Sweden generates about 110 million tonne of wastes every year. More than three-quarters of this is rock and other mine debris. Other major flows are dredged materials dumped into the sea and excavated soil. In comparison the amount of household waste is quite small: 4.3 million tonnes. However this has steadily increased over the last century, at about the same rate as households get more money to spend. In recent years this upward trend seems to have been broken, but it is too early to tell if this will last.

Waste from industrial and other activities have clearly increased as overall production has increased. However, it is difficult to directly compare this with economic development as the concept of waste has been applied differently in different studies. For example, some flows previously reported as waste are in later studies regarded as by-products. These include wood waste from sawmills, high-grade scrap metal and some residues from iron and steel works.

In TOSUWAMA we have studied household waste and most flows of industrial waste, including waste from the agriculture, forestry, construction, energy and service sectors. However, our calculations have not usually included mine waste, sludge from water treatment plants, sewage sludge,

contaminated soil and a few other flows. The flows we have examined covered in 2006 a total of 20 million tonnes. Of this 10 per cent was so-called hazardous waste. This includes chemical waste, but also, for example, scrapped vehicles and some mineral waste.

Future Waste Quantities

Waste volumes in the future will largely depend on how different sectors of the industry evolve, on household consumption patterns, and on technological developments. We have estimated future waste quantities in five scenarios (see Figure 3). In all these scenarios the total amount of waste increases, and in none of them does it grow faster than the economy. Nonetheless there is a large difference between scenarios. This is because economic growth, consumption patterns and technological developments varies between the scenarios.

The trend towards increased waste streams is not sustainable. This is not so much a result of waste management in itself: this impacts the environment and costs many billions, but it also generates large quantities of recycled materials and energy in return. The primary environmental gain of keeping waste down is instead that the need to produce materials and goods is reduced. We save both raw materials and energy, and when we save energy in production processes we also reduce emissions from combustion. In one example, we anticipated a decrease in the amount of household waste by slightly more than five per cent. This led to a decrease in annual greenhouse gas emissions by about 300 000 tonnes of carbon dioxide equivalents (see Figure 4), which roughly corresponds to the amount of carbon dioxide emitted in a medium-sized Swedish municipality.

Increased Material Efficiency

The greatest environmental benefit of keeping the waste quantity down is that production of materials and goods decreases. The most important way to cut down the amount of waste might be to increase material efficiency, i.e., reduce the unnecessary use of materials in society.

There are many different ways to achieve increased material efficiency (see Table 1). Many of the strategies are uncontroversial, and some of them also have good spin-off effects: a small car for example, requires less fuel, resulting in more important environmental benefits than the actual material efficiency itself. Of course there are also exceptions, when material-efficient products have negative effects on the environment. Reducing the amount of insulation in buildings increases energy demands for heating, which usually costs more for the environment than it saves through lower materials production.

The purchase of small, expensive products may seem like luxury consumption and appear as a provocative recommendation, but this often leads to less materials consumption and less waste per national currency unit consumed. The same applies if we consume services rather than goods, e.g., going to the cinema, gym or massage-parlour instead of buying new clothes and gadgets.

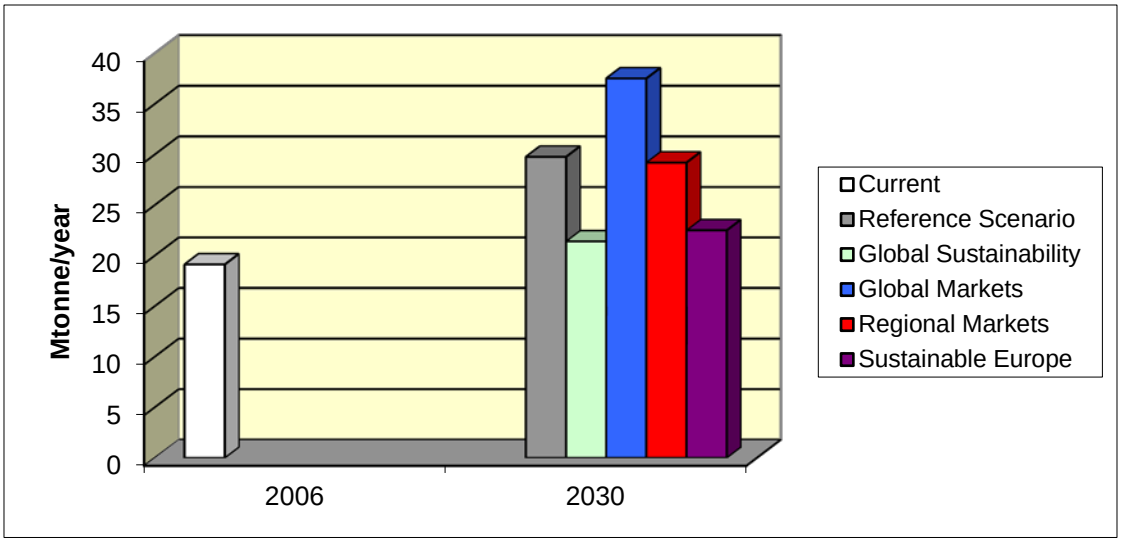


Figure 3. The waste quantity in 2006 and in five different scenarios for 2030. The scenarios differ in terms of economic growth, consumption patterns and technological development. More detailed description of the scenarios can be found in Dreborg and Tyskeng (2008). Calculations of the amount of waste are described by Sundqvist et al. (2010) and by Östblom et al. (2010).

Encouraging lower levels of consumption may seem provocative for exactly the opposite reason. But the more we buy, the larger the turnover of commodities in society will be. If we save money by buying less clothes and food, this money will still be spent on consumption later on. A long-term reduction of our consumption will require that we earn less money by, for example, working shorter hours. This opens up new avenues of research: Can the economy be sustainable without continuous growth and a constantly increasing consumption? If this is the case how will technological development and the environment be affected? These questions were not addressed in TOSUWAMA.

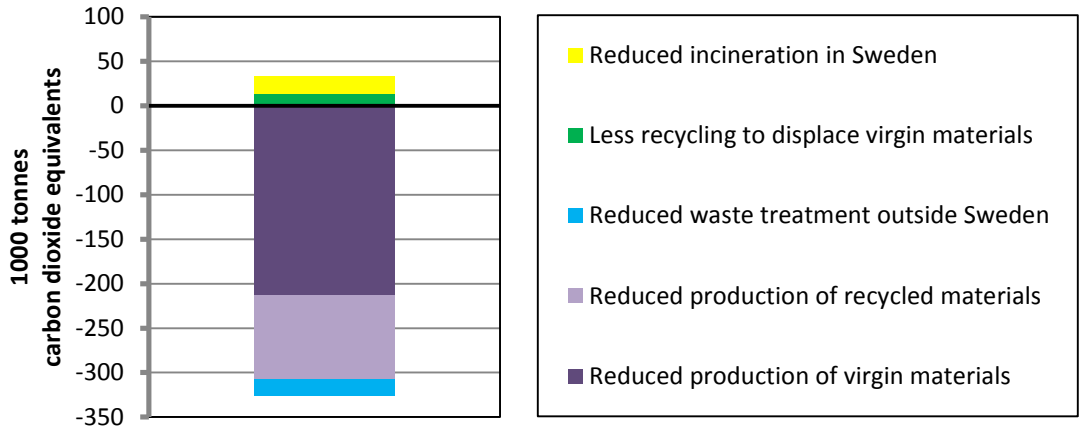


Figure 4. The figure shows how annual greenhouse gas emissions can be affected if Sweden generates five per cent less waste. The environmental benefits occurs mainly because production decreases for both virgin (i.e., new) materials and recycled materials. Source: Olofsson et al. 2004.

Policy Instruments for Material Efficiency

It may be difficult for the authorities to influence material efficiency to any great extent using policy instruments. Taxes and tariffs that make it more expensive to treat waste do not seem to help much. This is partly because the cost of waste management is usually very small compared to the purchase cost of materials and goods, and also because the cost of waste management is usually not taken into account at time of purchase.

Table 1. Strategies for increased material efficiency. Source: Ekvall 2008.

Strategy	***Examples***
Material-efficient processes	*Pre-fabricated construction of houses*
Material-lean products and systems	*Small cars,* *thin aluminium cans*
Products with a long service life	
High quality products	*Durability,* *high functionality,* *timeless design*
Repair	*Products that can be disassembled,* *production of spare parts*
Reuse	*In the home,* *through the second-hand market*
Consumption Patterns	
Leasing/co-ownership	*Car cooperatives*
Changing focus of consumption	*Services instead of goods,* *small, expensive products*
Consider the extent of consumption	*Work less,* *mend clothing,* *use leftovers*

Instruments that affect purchasing costs can be more effective. Reduced VAT for services and increased VAT on goods affect household consumption, so that a larger portion of disposable income is spent on services. If VAT on all services except transportation is reduced to six per cent the total waste quantity will be reduced by a per cent or so. This corresponds to a few hundred thousand tons of waste per year, which is a lot of materials but still far from enough to break the trend towards increasing waste volumes. More targeted instruments designed to stimulate second-hand markets, or to make repair services cheaper can be effective, but the amount of waste involved is probably rather small. Support for the development of material-saving technologies can help in the long run, but it is impossible to estimate by how much. A high commodity tax that makes extraction and the use of non-renewable materials more expensive could lead to increased material efficiency in industry. Such a tax needs to be designed carefully so that it does not have too large effect on the competitiveness of Swedish industry. This is discussed further in the section Stakeholders and Organizations below.

To some extent bans and injunctions from the authorities may also affect material efficiency and waste. A ban on the distribution of advertising to households that have not expressly given their consent would reduce the amount of paper waste generated by the public.

However, the amount of waste generated is probably predominantly determined by economic and technological developments, consumption patterns and lifestyle choices. It is doubtful whether and how policy instruments or similar measures can influence such factors. There is clearly room for further research here.

TOSUWAMA Publications (see www.sustainablewaste.info)

Dreborg K-H, Tyskeng S. (2008) Framtida förutsättningar för en hållbar avfallshantering – Övergripande omvärldsscenarier samt referensscenario. TRITA-INFRA-FMS 2008:6. Royal Institute of Technology, Stockholm.

Ekvall T. (2008) Waste prevention: Environmental effects and policy instruments. Nordic Workshop – Waste Resource Management and Climate Actions, Fredrikstad, Norway, June 10th, 2008.

Ekvall T, Sahlin J, Sundberg J. (2010) Effects of policy instruments on waste intensities. Report B1939. IVL Swedish Environmental Research Institute, Stockholm.

Forsfält T. (2011) Samhällsekonomiska effekter av två styrmedel för minskade avfallsmängder. Specialstudier nr 26. National Institute of Economic Research, Stockholm.

Östblom G, Ljunggren Söderman M, Sjöström M. (2010) Analysing Future Waste Generation – Soft Linking a Model for Waste Management with a CGE-model for Sweden. Working paper no. 118. National Institute of Economic Research, Stockholm.

Profu (2009) Approximation of marginal cost functions for waste prevention in Sweden – input data for modeling. Profu AB, Mölndal.

Sjöström M, Östblom G. (2009) Future Waste Scenarios for Sweden Based on a CGE-model. Working Paper no. 109. National Institute of Economic Research, Stockholm.

Sundqvist J-O, Stenmarck Å, Ekvall T. (2010) Model for future waste generation. Report B1933. IVL Swedish Environmental Research Institute , Stockholm.

Additional literature

Avfall Sverige (2011) Svensk Avfallshantering. Avfall Sverige – Swedish Waste Management, Malmö.

NV (2010) Avfall i Sverige 2008. Rapport 6362. Swedish Environmental Protection Agency, Stockholm.

Olofsson M, Ekvall T, Studz J, Sundberg J. (2004) Impacts of Swedish waste prevention and the scrap market equilibrium on greenhouse gas emissions. In Olofsson M. Improving model-based systems analysis of waste management. PhD thesis, Chalmers University of Technology.


Waste Management

Despite the improvements that have taken place in waste management during last two decades there is still an untapped potential for reducing the environmental impact of Swedish waste management practices. The waste management also needs to become more efficient as long as the waste quantities continue to increase if the overall environmental impact is not to increase. Investments in new and expanded waste-treatment plants will also be necessary as the waste quantities rise. This is a great opportunity to improve and increase the recycling of materials and also to make other parts of the waste management more sustainable. But what policy instruments have the potential to influence technology changes in this way? And what would it cost?

We generate waste every day – either directly, we throw something away at work or at home, or indirectly by consuming something that gave rise to waste when it was produced. Waste has different sources and different properties. The total amount is very large. The complexity entailed in adapting waste management to the properties of all these waste materials – where, when and in what quantity the waste occurs and who generated it – is one of the challenges of waste management. If we are to successfully utilize waste as a resource multiple technologies are usually required, from sorting and collection to treatment and post-treatment (see Figure 5). Today a relatively high proportion of Swedish waste is recycled, but considerable amounts of waste are still sent to landfills or incinerated, despite being recyclable.

Analysing and Managing Waste

The focus of TOSUWAMA has been on finding instruments that can move waste to higher levels in the waste hierarchy, i.e., prevention and recycling. If we are to succeed in this, changes in waste management technologies are required, among other things. The complexity of the waste system makes it difficult to determine which instruments have the potential to influence technology change in the right direction. It can be difficult to predict whether a particular financial instrument will make the target technology cheaper compared to the techniques currently in use. The long-term perspective adds to the complexity since it is likely to bring changes such as increases in the volume of waste, advances in technology and changes in the price of materials and energy. What waste-

management capacity will be needed in Sweden in the future? How do energy and material prices affect the cost-efficiency of different technologies? Systems engineering models can be used in the analysis of issues at this level of complexity.

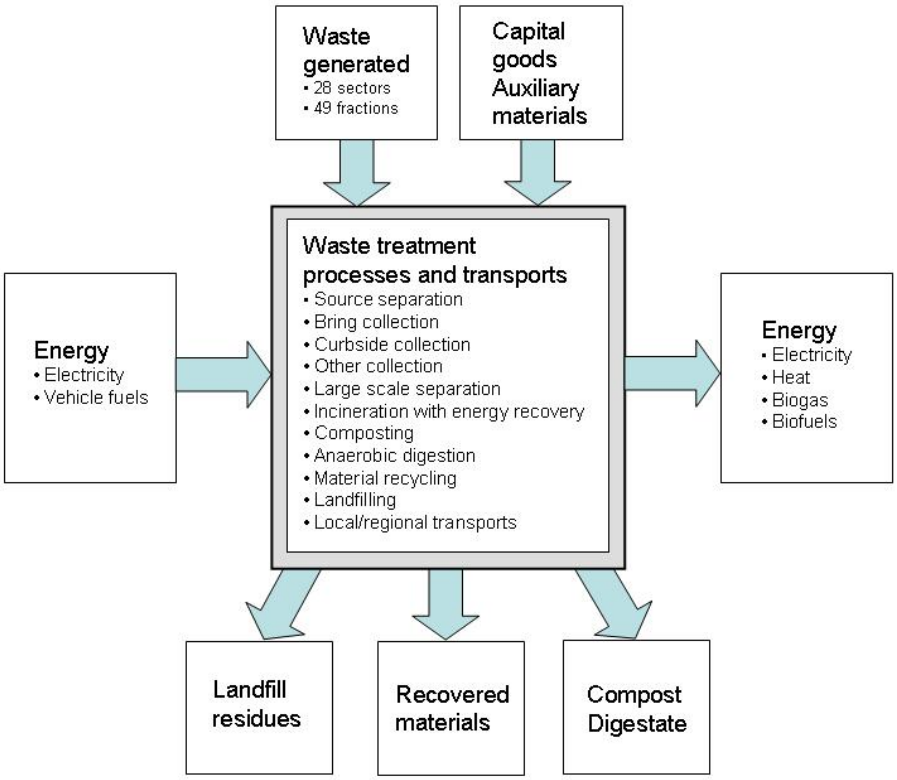


Figure 5. Waste management is carried out using a combination of technologies ranging from source separation and collection to treatment and post treatment. Source: Östblom et al. 2010.

In TOSUWAMA we used the NatWaste systems engineering model to analyse how policy instruments affect the economics of different technological choices in Swedish waste management (Ljunggren Söderman 2012). Most important in this analysis is the relationship between the net costs of different waste technologies and how the new instruments affect this relationship. If the instrument does not alter the relationship between the cost of e.g., incineration and anaerobic digestion sufficiently, the technologies currently in use will continue to be cost-efficient (i.e., have lower net costs or higher net revenues than all other available technologies) effective and the financial incentive for a technological change will be small. In such a case, the cost of managing the waste will be affected, but not the cost-efficient technology mix. In addition to the relationship between the net costs and revenues of waste technologies, the outcome of the analysis is also a function of the technical options that we chose to include, and the technical performance of these.

The Sustainable Waste Management programme also uses a number of future scenarios that incorporate economic growth, commodity prices, labour costs and emission allowances. They affect both the amount of waste to be handled and the cost of treatment.

The Capacity must probably be Expanded

It will probably be necessary to upgrade waste handling capacity in Sweden. The rate at which waste volumes will increase is uncertain, but the capacity for waste treatment needs, of course, to keep pace. In all our scenarios waste volumes are greater in 2030 than in 2006. In some the increase is modest but at most it is nearly twice as large, which means that we will have to almost double the treatment capacity. It is important to take advantage of the opportunity to steer waste management in Sweden in a more sustainable direction when investing heavily in new capacity, which in this case will definitely be needed.

Energy Recovery or Recycling?

When dealing with waste categories where the choice is between energy recovery through incineration or recycling, our analysis shows that energy recovery usually is the cost-efficient technology for system operators that is if environmental and other costs incurred on society as a whole are not taken into account. This is not particularly surprising – energy recovery through incineration generates comparatively high revenues and requires lesser pre-treatment in the form of separation at source or in a dedicated facility, and collection costs are often lower. Recycling results in higher costs for the collection of material and the recycling process. Much of today's recycling is therefore governed by different types of policy measures, for example, some form of producer responsibility, and not by purely financial incentives.

Even in the longer term, our analysis indicates that energy recovery is the most competitive technology. The price of both virgin and recycled materials may increase, but since the same applies to the price of the recovered energy, the relationship between energy recovery and recycling does not change enough for the latter to take over as the cost-efficient technology.

In contrast, recycling usually has a lower environmental impact than energy recovery through incineration. This has been previously shown in other studies and the environmental impact study of TOSUWAMA has arrived at similar conclusions (see Environmental Impact below). Which is the socio-economic efficient choice of technology, where both business economic costs and environmental impact should be taken into account depends, therefore, on what economic value is assigned to the environmental impact.

Energy through Incineration or Anaerobic Digestion?

For organic waste the choice is often between energy recovery through incineration and biological treatment by anaerobic digestion or composting. Our analysis shows that incineration is usually the cost-efficient technology for waste system operators. Biological treatment often entails higher

material collection costs, and the total revenues from compost, digestate and biogas are also lower than revenues generated by heat and electricity obtained via energy recovery.

On the other hand if biogas from anaerobic digestion is used as fuel for vehicles this often gives a greater environmental benefit than energy recovery through incineration. This has been shown in earlier studies and was confirmed by environmental impact assessments carried out in TOSUWAMA. Here as well the socio-economic efficient choice of technology depends on how highly the environmental impacts are valued.

Incineration with combined heat-and-power production (CHP) is more resource-efficient and better for the environment compared to incineration to produce hot water. Results from NatWaste indicate that it is also cost efficient. This means that rigorous policy instruments to promote cogeneration via waste incineration are not likely to be necessary in the future.

Legal Instruments

One of the instruments analysed using NatWaste affects the cost-efficient technology mix considerably – compulsory recycling of recyclable waste. This is a mandatory instrument that clearly shifts the emphasis away from incineration and landfill to recycling and biological treatment. The cost of the technology change needed to meet this requirement depends on how strictly "recyclable waste" is defined. If paper, cardboard, plastic, glass, metal and rubber are included in the definition, this amounts to 2.7 million tonnes of waste per year, and direct annual costs increase by approximately 7-10 billion SEK (Ambell et al 2010). The potential reduction in environmental impact may be in the same range or even higher, depending on how the environment is valued in monetary terms. In other words, such a change can be economically viable for the society as a whole.

Several of the policy instruments analysed has no effect on the cost-efficient technology mix in NatWaste, or cause only minor shifts. This depends on several factors, alone or in combination: the instruments in our studies might be too weak to have any effect, many types of waste are not affected by all instruments, regardless of level, and the NatWaste model does not include all (although many) possibilities of technology change. For example, a significantly higher climate tax than the one we investigated can provide a sufficient financial incentive to sort out fossil material for recycling. An instrument that focuses on promoting biogas production is another possibility.

Other changes that can move waste management to a higher level in the waste hierarchy are increased revenues for recycled materials, digestate and compost. Technologies that provide lower costs for recycling and anaerobic digestion could also influence the technology choices that will be cost-efficient in the future. This could be achieved through specific support to further development of these as yet less established techniques.

TOSUWAMA Publications (see www.sustainablewaste.info)

Ekvall T, Björklund A, Eriksson O, Östblom G, Sjöström M, Söderman ML, Stenmarck Å, Sundqvist J-O. (2009) Modelling to assess policy instruments. Proceedings of 12th International Waste Management and Landfill Symposium, 5-9 October 2009.

Ljunggren Söderman M (2012) Ekonomisk analys av nya styrmedel för hanteringen av svenskt avfall. Report B2021, IVL Swedish Environmental Research Institute, Gothenburg (manuscript).

Ljunggren Söderman M, Björklund A, Ekvall T, Eriksson O, Östblom G, Sjöström M, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for assessing policy instruments for a more sustainable waste management. Proceedings of 4th International Conference on Life Cycle Management, Cape Town, 6-9 September 2009.

Ljunggren Söderman M, Björklund A, Eriksson O, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for analysing policy instruments towards a more sustainable waste management. Proceedings of SETAC Europe 19th Annual Meeting, 31 Maj - 4 June 2009, Gothenburg.

Ljunggren Söderman M, Björklund A, Ekvall T, Eriksson O, Forsfält, T, Stenmarck Å, Sundqvist J-O. (2011) Policy instruments for a more sustainable waste management. Proceedings of 5th International conference on Life Cycle Management, Berlin, 29-31 August 2011.

Ljunggren Söderman M, Gottberg A. (2012) Kostnader och intäkter för avfallshantering i NatWaste. IVL Swedish Environmental Research Institute, Gothenburg (manuscript).

Östblom G, Ljunggren Söderman M, Sjöström M. (2010) Analysing future solid waste generation – soft linking a model of waste management with a CGE-model for Sweden. Working paper 118, National Institute of Economic Research, Stockholm.

Additional Literature

Ambell C, Björklund A, Ljunggren Söderman M. (2010) Potential för ökad återvinning av hushållsavfall och industriavfall. TRITA-INFRA-FMS; 2010:4. Royal Institute of Technology, Stockholm.

Ljunggren Söderman M. (2003) Recovering energy from waste in Sweden – a systems engineering study. Resources, Conservation and Recycling 38(2): 89-121.

Environmental Impact

Many policy instruments can contribute to reducing environmental impact through increased recycling and to some extent also through waste prevention. Among the instruments that we have studied using life cycle assessments the mandatory recycling of recyclable materials and the introduction of weight-based waste tariffs can have significant effects. The environmental gain from weight-based tariffs will depend on how people react to paying for each kilo of unsorted waste.

Waste management affects the environment through emissions from waste system processes and the consumption of electricity, fuel and other inputs. But equally important is that waste management also provides environmental benefits by producing materials, heat, electrical energy and nutrients that reduce the environmental impact in other sectors – energy, materials production and agriculture. Since the environmental benefits are often greater than the environmental impact of the waste system itself, waste management as a whole provides an environmental gain (see the introductory section and Figure 1). When planning and designing waste management practices it is a good idea to begin with life cycle assessments as this will enable us to take the most important environmental aspects into account.

In TOSUWAMA we have developed a model with a life-cycle perspective, SWEA, which allows us to assess how different waste policy instruments affect the environment. Carrying out environmental assessments of new policy instruments ensures that they really do contribute to more sustainable waste management.

Our environmental assessments of the various policy instruments are based on results from the EMEC and NatWaste models that show us how policy instruments affect the size of waste flows and the management of this waste. For each instrument we have compared the environmental impacts and benefits of the waste-management system with a no-policy scenario, i.e., the state the system would be in if the instrument had not been introduced. For instruments designed to prevent waste – taxes on raw materials, weight-based waste tariffs and changed VAT rules – we also took into account that the environmental impact is reduced when less material have to be produced.

Waste Prevention is Better than Recycling

Our results show that several of the studied policy instruments can have positive effects on the environment. One example is the introduction of a weight-based waste tariff where households and businesses pay for each kilo of unsorted waste. Provided that people are encouraged to recycle more such a tariff means that the environmental gain of waste management will be even greater. With regard to climate change the environmental gain can increase by 25 per cent.

If weight-based waste management tariffs instead encourage households to generate less overall waste, the system will have less waste to deal with and both recycling and waste will generate less climate benefits. On the other hand, greenhouse gas emissions from the production of materials will

be reduced. In total there will be an environmental gain with regard to greenhouse gases by up to 90 per cent, compared to the no-policy scenario (see Figure 6). This confirms the general rule that it is better for the environment to prevent waste than to recycle it.

Weight-based waste tariffs also reduce the emissions of other pollutants, as well as the use of non-renewable resources. However there might be no positive environmental effect if the instrument leads to an increase in illegal waste disposal.

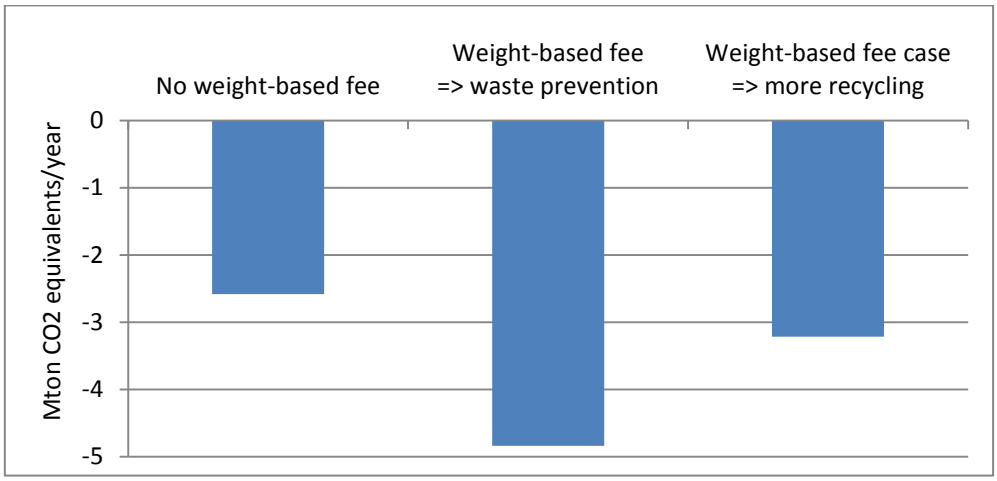


Figure 6. Climate impact of the waste-management system in a no-policy scenario and with a weight-based waste tariff resulting in waste prevention or increased recycling.

In a complementary project Ambell et al. (2010) studied the environmental benefits of a dramatic increase in recycling. The result shows that tougher instruments, such as the requirement that all recyclable materials must be recycled, can have a very positive impact on the environment (see Figure 1).

The model indicates that policy instruments such as a tax on raw materials and changes in VAT rules can also deliver environmental benefits, but the effects are not very large for the specific cases of these instruments that we have studied. Also the tax on waste incineration that we examined is expected to provide some environmental gains. This suggests that many policy instruments can be beneficial to the environment; however, the effects of some of them are quite limited, indicating that tougher instruments are required if more significant change is to be achieved. One such forceful policy instrument is to make the recycling of all recyclables compulsory.

An Optimal Waste-Management System

Our studies show that waste and recycling are important components in the waste-management system. An increase in recycling, especially of metals and textiles, contributes significantly to positive environmental effects. Sometimes pre-processing of waste makes the recycling more favourable to the environment.

Waste incineration can be said to be good for the environment as the energy generated can be used to produce heat and electricity, but incineration can also give rise to harmful gas emissions, for example when plastics are incinerated. Taking greenhouse gases into consideration, landfill and storage of plastics may be better options than incineration.

The TOSUWAMA research programme and related projects allow us to describe an optimal waste-management system that will reduce the emissions of greenhouse gases and other environmental impacts. This system will incorporate both measures to prevent waste and a level of recycling close to the technically feasible maximum. In such a system biowaste is collected separately and treated through anaerobic digestion. The biogas obtained is used as fuel for vehicles. Incineration is especially suitable for waste considered as biofuel. Incineration can also be used for materials that contain harmful chemicals and should not be recycled. Incineration should take place in cogeneration plants that produce both heat and electricity. Landfill is used only for waste that cannot be handled in any other way, and for plastics that are neither biologically degradable nor recyclable.

TOSUWAMA publications (see www.sustainablewaste.info)

Arushanyan, Y., Björklund, A., Eriksson, O., Finnveden, G., Ljunggren-Söderman, M., Sundqvist, J.-O., Stenmarck Å. (2012) Environmental assessment of waste policy instruments in Sweden (manuscript).

Björklund A, Finnveden G. (2007) Life cycle assessment of a national policy proposal – The case of a proposed waste incineration tax. Waste management 27:1046-1058.

Björklund A, Eriksson O, Ljunggren Söderman M, Stenmarck Å, Sundqvist J-O. (2009) LCA of Policy Instruments for Sustainable Waste Management. Waste and Climate Conference, Proceedings of ISWA and DAKOFA, 26-27 November 2009, Copenhagen, Denmark.

Björklund A, Finnveden G, Roth L. (2011) Application of LCA to waste management. In Christensen, T.H. (ed.): Solid waste technology and management Vol 1: 137-160. Wiley, Chichester, U.K.

Ekvall T, Assefa G, Björklund A, Eriksson O, Finnveden G. (2007) What life-cycle assessment does and doesn't do in assessments of waste management. Waste Management 27(8):989-996.

Ekvall T, Assefa G, Björklund A, Eriksson O, Finnveden G. (2007) Limitations and amendments in life-cycle assessment on waste management. Proceedings of SARDINIA 2007 - 11th International Waste Management and Landfill Symposium, Cagliari, October 2007:115-116.

Ekvall T, Björklund A, Eriksson O, Östblom G, Sjöström M, Söderman ML, Stenmarck Å, Sundqvist J-O. (2009) Modelling to assess policy instruments. Proceedings of 12th International Waste Management and Landfill Symposium, 5-9 October 2009.

Eriksson O, Finnveden G. (2009) Plastic waste as a fuel – CO2-neutral or not? Energy and Environmental Science 2:907-914.

Finnveden G. (2010) Life Cycle Assessment and Waste management – Lessons for Industry and Policy Makers. 3rd International Conference on Engineering for waste and biomass valorization, 17-19 May 2010, Beijing, p. 144.

Finnveden G, Roth L. (2008) Extending the Swedish Producer Responsibility? In Proceedings of Global Waste Management Symposium, 7-10 September 2008, Copper Mountains, Colorado.

Finnveden G, Tyskeng S. (2008) Comparison of Energy Use and Environmental Impacts of Recycling and Incineration. In Proceedings of Global Waste Management Symposium, 7-10 September 2008, Copper Mountains, Colorado.

Finnveden G, Björklund A, Moberg Å, Ekvall T. (2007) Environmental and economic assessment methods for waste management decision-support: possibilities and limitations. Waste Management and Research 25(3):263-269.

Finnveden G, Björklund A, Carlsson Reich M, Eriksson O, Sörbom A. (2007) Flexible and robust strategies for waste management in Sweden. Waste Management 27: S1-S7.

Finnveden G, Hauschild M, Ekvall T, Guinée J, Heijungs R, Hellweg S, Koehler A, Pennington D, Suh S. (2009) Recent developments in Life Cycle Assessment. Journal of Environmental Management 91:1-21.

Gentil EC, Damgaard A, Hauschild M, Finnveden G, Eriksson O, Thorneloe S, Kaplan PO, Barlaz M, Muller O, Matsui Y, Ii R, Christensen TH. (2010) Models for waste Life Cycle Assessment: review of technical assumptions. Waste management 30:2636-2648.

Johansson J, Björklund A. (2010) Reducing life cycle environmental impacts of WEEE recycling by introducing a targeted disassembly operation. Case study on dishwashers. Journal of Industrial Ecology 14:258-269.

Ljunggren Söderman M, Björklund A, Ekvall T, Eriksson O, Östblom G, Sjöström M, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for assessing policy instruments for a more sustainable waste management. Proceedings of 4th International Conference on Life Cycle Management, Cape Town, 6-9 September 2009.

Ljunggren Söderman M, Björklund A, Eriksson O, Stenmarck Å, Sundqvist J-O. (2009) An integrated concept for analysing policy instruments towards a more sustainable waste management. Proceedings of SETAC Europe 19th Annual Meeting, 31 May - 4 June 2009, Gothenburg.

Tyskeng S, Finnveden G. (2010) Comparing energy use and environmental impacts of recycling and incineration. Journal of Environmental Engineering 136:744-748.

Additional Literature

Ambell C, Björklund A, Ljunggren Söderman M. (2010) Potential för ökad återvinning av hushållsavfall och industriavfall. TRITA-INFRA-FMS; 2010:4. Royal Institute of Technology, Stockholm.

Habits and Behaviour

Most people have a positive attitude towards recycling. But if we are to make the waste system more sustainable from the household perspective it is important to reduce the uncertainty surrounding the waste management, and to encourage everyone to do their part. Although many people are positive to source separation and really want to contribute to a healthy environment, there are definite limits as to how much effort they are willing to make, although this will vary from individual to individual. This means it must be easy to do the right thing.

Two projects in the TOSUWAMA programme focussed on the habits and behaviour of people. In one case we examined from a psychological point of view how people assimilate information, and based on this, discussed opportunities for development in a day-to-day perspective. In the second project, we used a cultural perspective to examine what people think about waste management and what they actually do.

Sorting in Everyday Life

The interviews we conducted show that people see a lack of comprehensive solutions for the daily management of waste and recycling. Many people point out that kitchens have not been designed to facilitate recycling. Leftover food is messy and smells bad and this is seen as a problem – not just for themselves but also in relations with neighbours and colleagues. This may also lead to fraught social interaction, especially with regards to waste and waste areas. People have different ideas as to the amount of care and effort that should be exercised in connection with waste disposal and also on how bulky waste, packaging, etc., should be disposed of. Rules for what should be sorted where are interpreted differently. This in turn was connected to uncertainty about the individual responsibilities of the people concerned. At home this is often a question of how responsibility is to be divided

between the households, landlords, sanitation workers, and the municipality. In the workplace, it is also about different categories of staff having varying, and often unclear, degrees of responsibility for waste disposal. Finally the overall division of responsibility between public and commercial actors is interpreted differently, which leads to problems.

Despite the problems apparent from interviews and our analysis we found a fundamentally positive attitude towards recycling. Many want to contribute to a healthy environment by separating their refuse at source. We could notice a difference in this attitude related to the degree of anonymity in neighbourhoods. Waste disposal behaviour improves when individuals enjoy a personal relationship with neighbours, landlords and housing associations.

For most people sorting according to material is more logical than sorting by packaging. Packaging is seen as problematic to sort when it is hard to ascertain the composition and when it is made of mixed materials. The same is true of packaging and other materials that are to be disposed of as residual waste, such as porcelain and styrofoam. The fact that many articles cannot be recycled often diminishes the feelings of satisfaction an individual derives from his or her own sorting efforts.

To sum things up, attitudes to source separation can be located on a continuum with “satisfied” at one end and “uncertain” at the other. Satisfaction is the perception of recycling as a meaningful action that has a positive effect on the environment. Uncertain, on the other hand, is due to a variety of causes. It can be formulated as unanswered questions: What happens to the waste that I have left at the recycling points? Can I leave each packaging whole, or should I separate it into the different materials it is composed of, even when these are difficult to determine or are mixed? Is it worthwhile making the effort to sort things properly if other people or groups don’t? Why do symbols, concepts, waste fractions and their names vary between different locations and settings?

Source Separation at Work

The way in which waste management is organized differs between workplaces, even between workplaces of a similar kind. This is shown by our studies on hospitals, construction sites and offices in the Stockholm area. The responsibility for different parts of the internal waste system – who generates the waste, who separates it, who oversees this sorting, etc. – this seems only rarely to be a subject for internal discussions and deliberate changes. It is also often unclear to what extent it is up to the individual employee to take responsibility for the waste management. The balance is important between following rules and being autonomous when it comes to waste management at work.

In hospitals and construction sites the people actually responsible for source separation are not part of management, but an appointed “responsible” person. There are two kinds of problems associated with this role. One is the lack of the authority to make innovative decisions and implement them. The role is often restricted by given guidelines. The validity of the person’s responsibility is therefore uncertain. The appointed person does not have the tools to guarantee sustainable waste management in the workplace. The other problem is that locally appointed person often lacks the knowledge and evidence to show that the guidelines they follow and the practices they implement really are the best options from an environmental point of view.

There are two possible approaches to how waste disposal at home and at work relates to each other. One is to attempt to apply the same skills and adopt similar habits both at work and in private; the other is to maintain the differences between ways of doing things in these two everyday environments. It appears that those with a strong commitment to recycling want to achieve the same level of recycling and waste minimization both at work at home, while less active people passively accept different degrees of recovery and recycling at home and at work.

We observed that large fractions are not recycled in the workplace. For example a large proportion of the waste generated at the construction and healthcare workplaces we studied ends up in the combustible mixed waste fraction. In healthcare institutions the waste intended for incineration is called household waste. It consists largely of hygiene and health care materials, disposable products that have been in contact with patients or used in cleaning or other routine tasks. On construction sites the residual waste that is to be incinerated is known as PWP – paper, wood and plastics. Wood used for scaffolding and temporary structures rather than building materials makes up a large proportion of the PWP. Since the total amount of waste produced in offices is relatively small, the household-like waste generated by individuals such as foodstuffs and their packaging, newspapers, etc., makes up a relatively high proportion. The importance of household-like waste seems to be underestimated in the office, in the same way as the mixed waste intended for incineration is underestimated in healthcare and construction workplaces. In all these types of workplaces there is a tendency to regard the waste fractions going to incineration as unimportant.

Confidence that the waste is handled properly from an environmental point of view and that it is easy and convenient to do things in an eco-friendly way, are important in the workplace just as at home. But organization and sector-specific advice can also be given. Waste management seems to be well organized in hospitals and construction sites. Policies and procedures are detailed and rigorous, and the categories of staff that handle waste are often well informed and motivated. But compliance still appears to be better in healthcare institutions than at construction sites. This is partly because hospitals usually have a permanent location, while construction sites change all the time. Also, construction companies often have to deal with a large number of subcontractors. For this reason it is difficult to establish really good routines and practical solutions at construction sites. Both workplaces generate substantial amounts of mixed waste intended for incineration. Waste management might be improved in healthcare institutions by changing regulations, organization and waste classifications in combination with some form of financial instrument that ensured that reusable materials and increased recycling would not make the healthcare more expensive. This type of measures is also needed for the construction industry, but here mobility and the supply chain must be taken into consideration. It would also be desirable to establish a second-hand market for e.g., waste wood from construction sites.

The above line of reasoning implies that it might be possible to reduce the amount of waste: a smaller proportion of disposable products in healthcare, better reuse of wood in the construction industry. In addition, recycling could increase for, e.g., plastic, wood, insulation and gypsum in construction and plastic in hospitals.

Office workplaces have not come as far as the healthcare and construction sectors when it comes to organizing waste management. There is scope for improving routines and imposing stricter requirements to increase the proportion of separated waste.

Information as a Policy Instrument

Studies on social and environmental psychology show that it is difficult for mass communications to reach and influence the intended recipient. Even when information reaches its target, only a fraction of it is heeded. One reason is that the recipient can choose to ignore the information; another is that it is difficult for the sender to design the information to adequately target the desired audience. In addition, information usually has very little effect on behaviour. If it is to have an impact it must be carefully designed and combined with other measures and instruments.

Environmental information has so far largely been aimed at increasing knowledge, based on the belief that lack of knowledge is the reason why people don't sort their garbage. But research shows that increased knowledge by itself is not enough to change behaviour, although a certain amount of knowledge is necessary for this to happen. Information that highlights the moral implications of going green and that activates individual and social norms may have a greater effect on behaviour.

Another, somewhat inaccurate, notion is that the recipient is passive and willing to notice and digest information. In reality, everyone possesses a unique set of traits – pre-understanding, knowledge, perception, motivation and attention. The recipient can be someone who is sceptical to the message, eager to learn something new, passive and bored, uninterested, or lack experience in the topic.

People in general are different in terms of the values, goals and ethics they hold important. Even people in the same household differ. Hence, the same information is rarely relevant for all types of households, or even for all individuals within the same household. Information should be tailored to the target audience and designed to be consistent with the individual's values and goals. It is also important that the information stresses that individual contributions will make a difference. Otherwise there is a risk that the personal contributions will be dismissed as unnecessary, and when this is the case the majority will refrain from acting.

Information and Behaviour

The transition from an old established habit to a new one usually necessitates several separate steps. The process can be seen as a behavioural chain, and depending on where an individual is in the sequence there is a need for different types of information. At the beginning of the changeover the individual should be alerted to the current behaviour and its consequences. When the individual has become aware of these consequences he or she should be informed about alternative ways of behaving and the positive impact these will have. After that the moral aspects – what should be done to gain the approval of others – might prompt the individual to try out new ways of doing things. Finally, information that shows what other people do can be used to reinforce the pattern of behaviour – this new behaviour is supported by sharing a common idea with others about what constitutes the proper way of doing things.

Here is an example of an alert “Waste can be separated here”. Information about the benefits of changed behaviour can be expressed as follows “Source-separating waste saves the earth's resources”, or “If you separate waste at source you help conserve the earth's resources”. Information containing a moral message in “Mind where you through your rubbish!”

In our studies we have investigated whether attitudes, knowledge and norms can explain the level of variation in recycling behaviour. An important conclusion is that recycling is not a single act of behaviour, but several different ones. Each type of behaviour requires its own particular effort and information. People seldom regard source separating paper, cardboard and glass as a big effort. These fractions are also the ones most commonly recycled in households. However, sorting organic waste and different plastic materials is something that many people find difficult and it is also carried out less frequently.

Unfortunately, research in environmental psychology shows that in many situations positive attitudes towards the environment in general have a weak correlation with eco-friendly actions. It is unclear whether this gap is due to a lack of knowledge or if it reflects the fact that strong positive attitudes towards environmental issues in general do not necessarily encourage people to extend and deepen their knowledge.

If a particular behaviour is perceived as easy to perform, a positive attitude toward source separation may induce people to adopt it. However, this is not the only requirement. To get people to do something that involves any sacrifice, without an immediate reward to themselves, requires not only that it is relatively easy to perform, but also that the individuals concerned are motivated, aware of the negative consequences that ensue if the behaviour is not performed, believe it to be useful, that it is effective, that other people do it, and that they also have a positive attitude toward the behaviour.

When the new behaviour is perceived as difficult, positive attitudes are less important. It is apparent that a lack of knowledge is one of the biggest obstacles to source sorting among people who otherwise have a positive attitude towards the environment, but still do not separate at source. In order to bring about behaviour that is perceived as difficult so-called procedural knowledge is important – that is a learned ability to perform actions. It is also important that the individual has a personal commitment to eco-friendly actions and to separating waste at source.

Information that Works!

One way to achieve this is to make use of person-to-person communication in the form of "waste coaches" or "waste clubs" through which households get the chance to ask relevant questions. Another important and underrated way of communicating is to allude to social norms, for example, "all of us in this housing association recycle". This appeals to the desire of an individual to belong to a group and conform to the behaviour of others in order to become accepted and liked. A third way is to ensure that information is easily accessible, unambiguous, and has a high educational value. After encountering a message or reading instructions, everyone should clearly understand what they should do and how.

It should also be noted that the prestige and credibility of the sender in the eyes of the recipient affects the perceived relevance of the information. Experts, celebrities and persons who the target audience identify with all have high status, which can inspire the recipient both to pay attention to and absorb the content of the information. Introducing environmental certification of the workplace proved to be motivating for starting or increasing recycling in the home, if the individual was actually aware that the workplace was environmentally certified.

Finally, it may be wise to link information on waste prevention to values other than the purely environmental, for example, economic and lifestyle values. Research shows that the choice of, for example, foodstuff is mainly driven by price, quality and taste, and not by whether they are environmentally friendly.

Policy instruments from a Psychological and Anthropological Perspective

The research programme TOSUWAMA required the researchers to develop and apply new methods– neither psychology nor anthropology is usually capable of predicting how policy instruments affect humans. Usually, the approach is to describe how people experience the effects of the instruments already in place. It was also a new approach to evaluate the instruments in different future scenarios. Both the scenarios and the instruments we evaluated were mentioned in the introductory section of this report. There are also references to other reports, where these are described in detail.

The main conclusions from this part of the policy assessment are as follows:

Information is important, but should mainly be used in combination with other instruments. Information materials should be designed so that they are suited to different target groups, rather than mass mailings and glossy campaigns. It should both provide information on effects and consequences, and explain how people should behave. Information is important in all our scenarios, but especially in the two that include strong political governance towards sustainability. The scenarios assume a higher degree of individual and social participation and responsibility, which in turn should engender a greater sensitivity to, and effect of, relevant knowledge and information. Information to companies and workplaces should take different form depending on whether it is directed to the management or employees.

The policy instrument **"Advertising? Yes Please!"** corresponds directly to the desire of many households to avoid unwanted advertising, and makes the provision and the principle behind it easy

for them to understand. According to this argument this instrument would appear to be most effective in one of the so-called sustainable scenarios. It is thought to have some effect even in the "regional market" scenario, as this scenario puts businesses under more pressure to advertise.

Warning labels on products containing hazardous substances can be an effective means of control. Most importantly, it can be more effective than positive labeling. This is because people are not usually aware that hazardous chemicals are used in products such as toys, clothing or household items for cooking. The fact that people care about their health may make negative product labeling more effective than positive. Negative chemical labelling is probably effective in all scenarios.

When it comes to **weight-based waste-collection fees** the variable part of the tariff can impact the effectiveness of the instrument. Other circumstances, such as media attention and possible links to other measures to, for example, facilitate separation at source, will affect the impact of the instrument. Weight-based waste tariffs are expected to be most effective in the market-driven scenarios where the individual is given a great deal of responsibility. In the sustainable scenarios people are likely to expect the state to take responsibility for keeping the amount of residual waste and its environmental impacts low. Then a "penalty tax" on waste is not motivated to the same degree and might be more negatively regarded.

Improved collection systems are expected to lead to increased recycling in all scenarios. This applies to both increased curbside collection and collection in material flows.

An **environmentally differentiated waste-collection fee** means that people who recycle pays less than those who do not. This can be a powerful instrument if it is properly communicated. Then this tariff and its effects on people can be equivalent to both the weight-based tariff and the improved collection system described above. The differentiated tariff instrument should ideally be able to link together these two incentives, which would be especially effective in a market-driven future.

Motivated and Satisfied or Indifferent and Uncertain?

To make the waste-management system more sustainable it is important to remove some of the uncertainty about waste management and increase people's motivation to contribute. Individuals and groups that strive to act in line with notions of what is necessary or good for the environment can be encouraged by measures designed to facilitate their actions to this end. In this context it is important that ordinary people and those managing the waste share a common understanding of the waste management and its consequences for the environment. If people are to feel satisfaction with their own efforts, they need to know that what they perceive to be major and for the environment important categories of waste, are disposed of properly. And, according to our investigations people feel that it is society, rather than waste contractors, materials companies or other interested parties that provides the ultimate guarantee that waste is disposed of properly. Therefore, national laws and local enforcement may be more effective than economic instruments and market mechanisms for maintaining confidence and motivation, at least under social conditions similar to those of today.

People want the environment to benefit as much as possible and that is why they contribute with their own recycling efforts. This means that they need to know that the environment comes first

when waste is treated, recycled and returned to nature or to society. This will help uphold the confidence in the waste system and the motivation to contribute to its workings.

But despite the fact that many put the environment first in connection with waste disposal there are clearly defined, although individually variable, limits as to how much people are willing to make an effort. Therefore, it must be easy to do the right thing. It is not enough that the authorities can guarantee that the waste system is environmentally friendly. The system must also be user friendly. "Do-it-for-me" may in practice be more in demand than "do-it-yourself". The overriding principles that should apply to waste operators and commodity producers are user-friendliness and simplification.

Resource efficient and environmentally friendly ways of managing goods and waste should be cheaper and more readily available than environmentally harmful ones. Development in this direction does not always require detailed knowledge and personal commitment on the part of individuals and households. Instead advances in this respect might take the form of collaboration between decision-makers in business and policy making – including international bodies such as the EU.

TOSUWAMA Publications (see www.sustainablewaste.info)

Åkesson L. (2006) (Ed.) Överflöd - mellan minnesvärt och bortglömt. Kulturen, Lund.

Åkesson L. (2007) Källsortering med förhinder. Avfall och miljö No. 1 2007: 14-15.

Åkesson L. (2008) Det värdelösas värde och sopornas ordning. In Cronqvist M (Ed.): Hållbara värden. Riksbankens jubileumsfond. Makadam förlag, Stockholm: 137-155.

Åkesson L. (2009) Waste and garbage as time travel. Lund Archaelogical Review 15: 95-98.

Åkesson L. (2012) Waste in overflow. In: Czarniawska B, Löfgren O. (Ed.) Managing Overflow in Affluent Societies. Routledge, London: 141-154.

Andersson M, von Borgstede C. (2010) Differentiation of determinants of low-cost and high-cost recycling. Journal of Environmental Psychology 30(4): 402-408.

Andersson M, von Borgstede C, Eriksson O, Guath M, Henriksson G, Sundqvist J-O, Åkesson L. (2011) Hållbar avfallshantering – utvärdering av styrmedel från ett psykologiskt och etnologiskt perspektiv. TRITA-INFRA-FMS 2011:5. Royal Institute of Technology, Stockholm.

Andersson M, Eriksson O, von Borgstede C. (2012) The Effects of Environmental Management Systems on Source Separation in the Work and Home Settings. Sustainability 4: 1292-1308.

Ewert S, Henriksson G, Åkesson L. (2009) Osäker eller nöjd – kulturella aspekter på vardagens avfallspraktik. Report TRITA-INFRA-FMS 2009:3. Royal Institute of Technology, Stockholm.

Henriksson G, Åkesson L, Ewert S. (2010) Uncertainty Regarding Waste Handling in Everyday Life. Sustainability 2: 2799-2813.

Henriksson G, Åkesson L, Ewert S. (2010) Uncertainties surrounding waste-sorting reduce household recycling. Science for Environment Policy, European Commission Newsletter.

Henriksson G, Börjesson M, Åkesson L. (2012) Environmental Policy Instruments Seen as Negotiations. In: Welz G, Sperling F, Blum E M. (Ed.) Negotiating Environmental Conflicts: Local communities, global policies. Publications of the Department of Cultural Anthropology and European Ethnology. Goethe-University. Frankfurt am Main. Band 81: 83-105.

Larsson K-A, Henriksson G, Ewert S. m.fl. (2010) Ett kulturvetenskapligt perspektiv på källsortering. In: Larsson K-A. (Ed.) Åter VINNARE för industrin 2010. Rekord Media och Produktion AB, Stockholm: 122-127.

von Borgstede C. (2008) Kunskap räcker inte för att ändra beteende. Avfall och miljö No. 3 2008.

von Borgstede C. (2010) Källsortering i psykologisk belysning. In: Larsson K-A (Ed.) Åter VINNARE för industrin 2010. Rekord Media och Produktion AB, Stockholm: 128-131.

von Borgstede C, Andersson K. (2010) Environmental Information – Explanatory Factors for Information Behavior. Sustainability 2: 2785-2798.

von Borgstede C, Andersson M, Hansla A. (2014) Value-congruent information processing: The role of issue involvement and argument strength. Basic and Applied Social Psychology 36(6): 461-477.

Stakeholders and Organizations

The feasibility of introducing a particular policy instrument and the effect it can have depends on whom it impacts and the ways in which this player may react. If it is to be effective, the instrument should target players who exert control over that which the policy instrument seeks to influence, whether it is the volume of waste, the danger it poses, the degree of source separation or something else.

Policies that attempt to prevent waste and increase recycling can be more or less feasible to implement. They can affect many kinds of stakeholders, and thus face opposition from different quarters – from waste management companies, households, material producers, and others.

The effect of an instrument also depends on the actors affected. Some of these can improve the way in which they operate in response to the instrument. In this case the introduction of the instrument has the desired effect. Other players might be unable to affect the situation, or they may move abroad or shut down when operations in Sweden become too expensive to compete at an international market. In this instance the instrument does not lead to increasing sustainability.

In TOSUWAMA we have carried out a stakeholder analysis to establish the effectiveness of three instruments: climate tax on waste incineration, tax on natural resources, and weight-based waste-collection fees (Ekvall et al. 2012).

Climate Tax on Waste Incineration

The climate tax we have studied is paid by the operators of facilities where waste plastics and similar fossil materials are incinerated (see Bisaillon et al. 2009). The tax is much lower for plants that produce both electricity and heat and therefore the owners of waste incineration plants are given a direct incentive for the cogeneration of electricity and heat. Cogeneration utilizes the energy contained in waste more efficiently. In this way the climate tax steers operators in the right direction.

With time, however, all waste incineration plants in Sweden are likely to cogenerate electricity and heat even without this tax (see the chapter Waste Management).

A climate tax can also be introduced to reduce waste incineration and increase materials recycling, especially with regard to plastics. But this effect is uncertain, at least with the current systems and technologies. It isn't the owners of the waste incineration plants who decide how much plastic that is recycled – this is determined by the households and businesses that choose or don't choose to source separate. With further technological development it may become possible for the incinerator plants themselves to separate the plastics from the waste delivered to them. In the future, it may also be possible to measure the plastic content in each shipment of waste. This would make it possible for waste incineration plants to charge companies for every kilo of plastic waste they deliver. This would give companies, if not households, a clear incentive to step up the source separation of plastic waste. Such solutions are more likely in future scenarios with rapid technological development.

All the incinerator operators can do with the current systems and technologies is to try to get people to recycle more. When the plants are owned by municipalities, they can make sorting easier, for example by offering curbside collection or other improvements in the collection system. Other ways to influence sorting can be through information campaigns, for example, under the auspices of the national business association Swedish Waste Management. However, the effects of such measures are unclear.

All in all, there is a clear risk that the models that do not take into account which players are affected exaggerate the impact climate tax have on plastics recycling. This is especially true for plastic waste from households. On the other hand, the tax helps increase the fees for processing mixed waste, which may lead to an increased biological treatment of kitchen and garden waste (Sahlin et al. 2007). It might also contribute marginally to the recycling of non-plastic materials, to a reduction of the total registered waste volume, and an increase in landfilling, incineration and recycling in other countries.

Raw-Materials Tax

The tax on raw materials that we analysed is a combination of two proposals that also can be implemented independently (Bisaillon et al. 2009). The first means that the tax currently levied on heating oil is broadened to include all use of fossil raw materials. The second means that all non-renewable materials mined or imported into Sweden are taxed at the same rate as current taxes on natural gravel. This tax is in practice higher for materials producers than for importers. Importers pay only for the tonnes of finished materials they import, while material producers also pay for every tonne of tailings and other extracted material that is unexploited and ends up as waste or is consumed in the manufacturing process.

This commodity tax is likely to reduce the amount of tailings by 3-3.5 per cent. The amount of plastic waste will also be somewhat reduced. The total amount of other Swedish waste flows will decrease by less than 0.2 per cent. It is also likely that the tax stimulates the use of renewable and recycled materials in Swedish plastics production.

The tax is not expected to affect growth in Sweden significantly but will reduce profits in the Swedish mining and the chemical industries. If the higher tax on fossil fuels is levied on coal and coke used as reducing agents this can completely wipe out Swedish ore-based steel production and also affect the production of other ore based metals.

The tax can be adjusted to mitigate its impact on competitiveness. For example, it can be based on the estimated amount of non-renewable raw materials extracted for the manufacture of goods intended for domestic use, regardless of whether raw materials and goods are produced within or outside Sweden. This type of revised tax is likely to reduce the amount of plastic and chemical waste. It would also provide an incentive to channel recycled plastics and renewable substitutes for fossil raw materials to industries producing primarily for the Swedish market. This creates something of a niche market for these raw materials, which can contribute to both the development of new recycling technologies and the establishment of a broader market for recycled and renewable raw materials in the chemical industry.

Since the adjustment of the tax aims to substantially reduce the impact on the competitiveness, the tax itself can be high. Perhaps it could be of the same order of magnitude as the cost of producing materials without tax. This would give both the chemical and engineering industries a stronger financial incentive to use raw materials efficiently, particularly when manufacturing for the Swedish market.

The consumption patterns of households and other end users are unlikely to be noticeably affected even by high raw-materials taxes. An increased cost of raw materials has less effect on the product price, the more they are processed, transported and handled. The material costs are usually only responsible for a very small fraction of the final price in the retail market.

Weight-based Waste-Collection Fee

Property owners are responsible for the costs of waste collection. A weight-based tariff gives households in most single-family houses a financial incentive to reduce the amount of residual waste. They can do this by reducing the total amount of waste or by recycling more. The introduction of a weight-based tariff also raises awareness about waste and waste management that can contribute to waste prevention and increased source separation, at least in the short term. But there is also a risk that weight-based waste tariffs will incite households to dispose of waste in various illegal ways.

Weight-based tariffs offer almost no financial incentive at all to households in apartment buildings. The levy each household pays will not be significantly affected by the amount of residual waste it generates. However, there is an incentive for the owners of apartment buildings to alert the residents to the problems of waste management and make source separation easier for them. Such measures can help increase recycling, but their impact is uncertain.

Statistics show that the total effect of introducing a weight-based waste-collection fee is significant, at least in the short term. Results from a survey in Gothenburg suggest that the effect is primarily due to greater awareness (Schmidt et al. 2012). It is unclear whether the financial incentive contributes in any noticeable way. The effect of a weight-based waste tariff will in the future probably be due to the priorities of the residents. Increasing the attention to waste management is

likely to be more effective in cases where there is a high level of general environmental awareness, while financial incentives are more important when homeowners focus more on economic issues. In the latter case, there is risk that the tariff will lead to increased illegal dumping and it is thus important to have an effective monitoring system in place.

Right Incentives to the Right Player

If an instrument is to be effective, it must deliver the right incentives to the right players – that is, to those who control that which the instrument is intended to influence. The instrument should be designed so that it targets the right stakeholders directly. For example, small-home owners are directly affected by the weight-based waste tariff.

In cases where the right incentives are already in place, an instrument can be effective by removing obstacles that impede correct behaviour.

Policy instruments can also provide incentives indirectly. A tax on waste incineration is charged to the owners of incinerators who do not have direct control over the level of source separation; however, they can instead remove obstacles that impede source separation and in this way encourage households and businesses to recycle more. The impact of an indirect incentive is difficult to predict and there is a risk that the regulatory effect of the instrument will be diluted and weakened.

TOSUWAMA publications (see www.sustainablewaste.info)

Bisaillon M, Finnveden G, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2009) Nya styrmedel inom avfallsområdet? TRITA-INFRA-FMS 2009:7. Royal Institute of Technology, Stockholm.

Ekvall T, Sundqvist J-O, Hemström K, Jensen C. (2012) Stakeholder analysis of incineration tax, raw material tax, and weight-based waste fee. IVL Swedish Environmental Research Institute, Stockholm (manuscript).

Sahlin J, Ekvall T, Bisaillon M, Sundberg J. (2007) Introduction of a waste incineration tax: Effects on the Swedish waste flows. Resources, Conservation and Recycling 51(4):827–846.

Additional Literature

Schmidt L, Sjöström J, Palm D, Ekvall T. (2012) Viktbaserad avfallstaxa: Vart tar avfallet vägen? Report B2054. IVL Swedish Environmental Research Institute, Stockholm.



Markets for Recycled Materials

The supply of recycled materials is often slow to react and only marginally affected by price changes. Therefore, the prices of these vary considerably over time. Instruments such as raw materials taxes or recycling certificates that attempt to boost the demand for recycled materials have only a marginal effect on recovery. To increase recycling these instruments should be combined with policies that increase the availability of recycled materials. In the case of materials for which efficient recycling markets do not yet exist this may require policies that stimulate the exchange of information between players.

How Recycling Markets Work

The recycling of materials has a long history. More or less global markets for scrap metal and waste paper have been developed over the last hundred years, mainly due to private initiatives and driven by economic motives. For other materials, such as recycled plastics, construction and demolition waste, markets are not as established. Since the early 1970s environmental and waste policies have played an increasingly important role for recycling in the community. Several policy instruments have been introduced to increase recycling. An important objective of waste-management policy is to stimulate the emergence of new recycling markets, i.e., conditions where companies find it profitable to sell recycled materials and buyers also see a financial gain in the use of the material in the manufacture of new products.

In the TOSUWAMA programme, we investigated how existing recycling markets work and analysed the conditions under which markets for new materials can be established. In this context, we also analysed the effects of different waste policy instruments, primarily raw-materials taxes and recycling certificates.

An important feature of recycled materials markets is that both supply and demand for the materials they trade in often responds very slowly to price changes. The supply of recycled materials can be rather insensitive to price changes even in the long term, because it depends on previous consumption patterns. The only source of recycled material is the waste from the products we previously manufactured and used. Our own studies, as well as earlier research, confirm the impression that supply is relatively insensitive to price changes of a variety of recycled materials, such as aluminium, steel and copper scrap and waste paper. The supply of new raw materials, so-

called virgin materials, is more flexible in the long term as new mines can open if the price of the material rises.

Many materials, for example metals, are used in sectors of the economy that tend to be sensitive to economic fluctuations: the construction and automobile industries, etc. Low price sensitivity in combination with the fact that short-term demand is a function of the state of the economy means that the price of recycled materials varies greatly. In most cases, the price volatility of recycled materials is greater than it is for the same commodity based on virgin raw material. This can inhibit the willingness to invest in production facilities that use recycled materials.

Effects of Raw-Materials Taxes and Recycling Certificates

The price sensitivity also affects how different policy instruments affect the use of recycled materials. A tax on virgin materials means that the use of recycled materials becomes more economically attractive, but if the supply cannot meet the increased demand recycling increases only marginally. This is confirmed by the experience in connection with the taxation of natural gravel and similar materials in a number of European countries. The Swedish tax on natural gravel has mainly led to an increase in the use of crushed stone, while the use of recycled materials, such as construction and demolition waste, has not increased by a similar amount. In England, a similar tax had the same effect, i.e., the use of other tax-exempt material has increased while the impact on the amount of recycled materials has been moderate.

Experience shows that if the goal is to increase recycling, raw-materials taxes must be combined with other policy measures designed to increase the supply of recovered material. Denmark has had a tax on raw materials since 1990, but the authorities have also introduced a requirement for sorting of construction and demolition waste, which has resulted in a substantial increase in the recycling rate of this waste flow.

Thus a raw-materials tax is not a particularly effective instrument for increasing recycling. In this regard measures that increase the availability of different used materials appear to be more efficient, such as sorting regulations, infrastructures to facilitate household source separation, and recycling subsidies. However in some cases, a raw-materials tax may help reduce waste by making material-intensive products more expensive. Thus a combination of raw-materials tax and other policy measures on the supply side can lead to both less waste and increased recycling of used products.

A system with recycling certificates means that users of a certain recycled materials in new products are given certificates equivalent to the amount of recycled materials used in their manufacture. The certificates can then be traded on a market. To ensure the demand for these certificates the authorities impose a quota on the user side, which indicates the proportion of the total material usage that must be based on recycled materials. An example of such a system is in place for packaging in the UK.

If a national system of recycling certificates is introduced for recycled materials traded within the country, this guarantees a certain market proportion for recycled materials, while providing flexibility for users – those with high recycling costs can buy their way out of the recycling obligation. Recycling certificates for metals, paper and plastics would have same effect if they could be introduced on a

global level. One disadvantage of such systems is the costs of the recycling certificates are uncertain and difficult to predict. As the supply of recycled materials is often price insensitive, the price of the certificates could be forced up to very high levels if an ambitious quota obligation must be fulfilled. To avoid this, a fixed fee to be paid by those who do not have enough certificates can be introduced. This provides an opportunity to buy exemption from the obligation to purchase certificates, which imposes a limit on the price of the certificates.

Overall, research shows that recycling certificates are probably not an efficient socio-economic policy instruments for waste management. They work best in situations where the supply of recycled material is sensitive to price changes and the environmental benefits of recycling include clear threshold effects. None of these conditions are usually met in the waste sector. Just as in the case of raw-materials taxes, recycling certificates make the use of materials more expensive and thus lead to less waste. If they are to encourage recycling in a socio-economically efficient manner they should be combined with policies that increase the availability of recycled materials.

National Waste Policy on Global Markets

We have drawn attention in our research to the problems of implementing national policies for recycled materials traded on international markets. If powerful instruments are only introduced in Sweden this can cause problems for the Swedish industry. The global environmental benefit can also vanish if an instrument forces businesses to move abroad. In such cases compensating instruments, such as earmarked tax revenues or the adaptation of the instrument to different sectors, may be advisable to neutralize the effects.

If recycling certificates are only introduced in a single country this can be quite ineffective. In the UK, the certificate system has sometimes led to recyclers exporting collected recyclables to other countries instead of investing in new infrastructure and recycling capacity.

If Sweden introduces a certificate system for materials such as metals, paper and plastics, this is unlikely to lead to a significant increase in the overall level of recovery, but will probably mean instead that more materials, that would be recycled anyway, will be redirected to Sweden. This in turn will lead to changing transport patterns, which could possibly increase the total environmental impact.

Establishing Effective Recycling Markets

Achieving efficient recycling markets is not just about traditional waste policy instruments such as extended producer responsibility, landfill taxes and deposit systems, but also about surmounting other obstacles that make it difficult to sell and buy recycled materials. We have identified a number of such obstacles, as well as policy measures that could effectively manage and overcome them.

Good information flows are important for the establishment of efficient recycling markets. The supplier often knows more about the properties of the material than the buyer. This can give rise to a situation where only materials of inferior quality are offered to the market. The problem is probably most prevalent in markets where different materials are mixed at the collection stage, as is

sometimes the case with construction and demolition waste and some plastics, and where buyers and sellers do not meet very often.

Lack of information can create problems on the user side and are common for e.g., plastics and construction and demolition waste, and partly also for paper and glass. Often this is a question of uncertainty about the quality of the recycled material. Even a relatively small uncertainty as to the value and usefulness of the material can have a significant impact on the demand, particularly if "recycled" is perceived as synonymous with poor quality. This may justify state support for demonstration projects, and also public procurement. The development of product standards is another measure that can alleviate this type of information problem.

Another important problem is that products are sometimes manufactured in a way that increases the cost of recycling the material in another sector or industry. An example of such unfavourable product design is the use of multiple colours in glass bottles; another is the use of certain plastics in cable manufacture. In these cases the recycler has little possibility to influence the producer or product designs. The state can help in several ways, for example by supporting research and promoting the demonstration of improved product design, by having mandatory rules for the recoverability of certain products or by requiring producers to provide information on how to disassemble and recycle a product. As the supply of recycled materials is difficult to influence through increased demand, it is probably often more important to design a product so that it can be easily recycled than to use recycled materials in the production of it.

Innovation Policy is Important!

In TOSUWAMA we have also studied the extent to which different instruments, such as EU directives, voluntary agreements and national legislation, have stimulated innovations that make it easier to recycle used products. These instruments have been implemented in a number of countries in the OECD area. Our analysis shows that voluntary agreements within European industry have had a positive effect on innovations that simplifies, for example, recycling of scrapped cars, while EU directives have had a more prominent role for innovations that facilitate recycling of plastic packaging.

An important role for innovation policy is to strike a balance between measures to improve the development of recyclable products and measures to improve waste management processes. Both are needed to achieve long-term cost-effective solutions.

TOSUWAMA publications (see www.sustainablewaste.info)

Blomberg J, Söderholm P. (2009) The Economics of Secondary Aluminium Supply: An Econometric Analysis Based on European Data. Resources, Conservation and Recycling 53(8):455-463.

Ejdemo T, Söderholm P. (2008) Steel Scrap Markets in Europe and the USA. Minerals and Energy 23(2):57-73.

Mansikkasalo A, Lundmark R, Söderholm P. (2014) Market Behavior and Policy in the Recycled Paper Industry: A Critical Survey of price Elasticity Research. Forest Policy and Economics 38:17-29.

Nicolli F, Johnstone N, Söderholm P. (2012) Resolving Failures in Recycling Markets: The Role of Technological Innovation. Environmental Economics and Policy Studies 14(3):261-288.

Söderholm P. (2011) Taxing Virgin Natural Resources: Lessons from Aggregates Taxation in Europe. Resources, Conservation and Recycling 55(11):911-922.

Söderholm P. (2011) Vad behövs för att etablera effektiva återvinningsmarknader? In K-A. Larsson (red.) Åter vinnare för industrin 2011. Rekord Media och Produktion AB, Stockholm, pp. 109-113.

Söderholm P, Ekvall T. (2012) Material Markets in the Presence of Secondary and Primary Production: Important Interactions and Policy Impacts (manuscript).

Söderholm P, Johnstone N. (2012) Market Inefficiencies in Recycling Markets: The Role of Public and Private Remedies (manuscript).

Söderholm P, Tilton JE. (2012) Material Efficiency: An Economic Perspective. Resources, Conservation and Recycling 61: 75-82.

Improved Recycling

Processes and systems for recycling and biological treatment can be improved significantly. In TOSUWAMA we investigated waste flows in three segments of this vast area – food waste, textiles and asphalt – and we saw a potential for environmental improvement in all three. Both reuse and recycling of textiles can increase dramatically, and there are promising opportunities for reducing energy use in the anaerobic digestion of food waste.

The environmental impact of landfilling and incineration has declined significantly over the past 25 years. This is due to major research efforts, technological developments and environmental regulations. There has not been a similar effort to improve the environmental performance of recycling processes and biological treatment. These processes are not as well developed and are often on a smaller scale compared to the production of new materials. Thus there may be a significant potential for environmental improvement in the recycling processes. If these processes affect the environment more than necessary it will be a problem, partly because of the unnecessary direct impact, but also because it makes it harder to defend recycling and biological treatment – even in cases where these processes are environmentally justified in the long run.

For this reason the TOSUWAMA programme included a dedicated project designed to investigate the possibility of improving the environmental performance of technologies and systems for recycling and biological treatment. The study focuses on three waste flows: asphalt, food waste and textile waste.

Asphalt Recycling

Old asphalt can be recycled and reused. Asphalt waste from public roads in Sweden is usually recycled to conserve natural resources and reduce landfill.

Recycling involves heating the reclaimed asphalt and adding it to the hot mix when new asphalt is being laid. This process can be carried out either in a stationary asphalt works or on site at the road. Reuse means that the old asphalt is pulverised and used as unbound layers without further treatment. Unfortunately, there is some confusion around the terms connected with recycling and reuse of asphalt, which cause difficulties when the amounts recycled are reported.

The results of our Life Cycle Assessment (Miliutenko et al. 2012b) shows that the hot recycling of asphalt reduces greenhouse gases when paving, whether recycling is done on site or at an asphalt works (see Figure 8). The uncertainty in the absolute numbers is great, but asphalt recycling delivers an environmental gain because it reduces the need for virgin bitumen. Recycling on site is the environmentally preferred option because fewer transports are necessary. However, this technology is only suitable for the maintenance of straight roads such as motorways and the like.

Figure 7. Recycling of asphalt on site and at an asphalt plant.

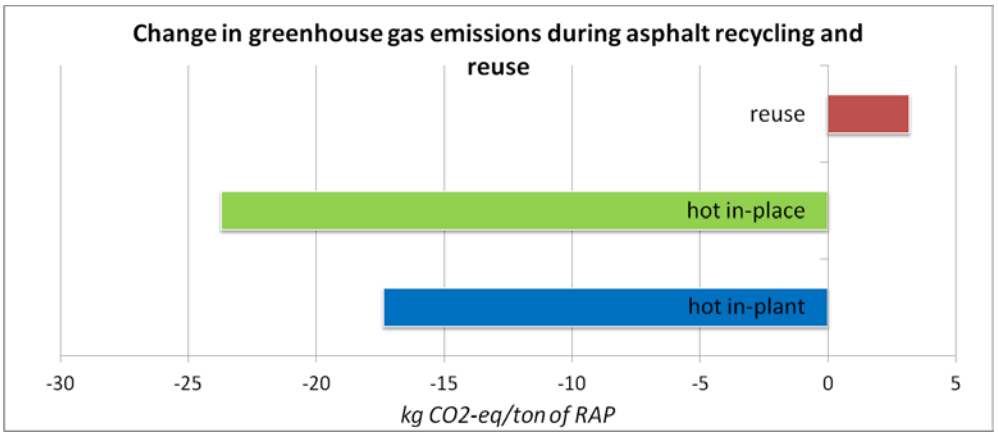


Figure 8. Change in greenhouse gas emissions from the reuse and recycling of asphalt, compared to use of virgin raw materials (Miliutenko et al. 2012b).

The reuse of old asphalt as unbound layers does not reduce greenhouse gas emissions (Figure 8). This is because the recycled asphalt does not replace the bitumen in the new asphalt, but only materials such as gravel and crushed stone. Extraction of new gravel and crushed stone causes less pollution than when the old asphalt is torn up, crushed and transported. But if the asphalt still needs to be removed, it may be better to reuse it than to put it in a landfill.

It is worth noting that the environmental performance of each of the options can be improved by logistical, technological and organizational innovation. If recycling of asphalt is to become more widespread it requires that also smaller players in the industry implement the technology. Both the Swedish Transport Administration and independent contractors could help smaller municipalities introduce asphalt recycling.

Anaerobic Digestion of Food Waste

The treatment of food waste can be improved by a careful choice of technology in existing and planned facilities. Pre-treatment of waste can increase the amount extracted biogas, but can also negatively affect the environment through increased use of electricity.

Our study of biological waste treatment focuses on anaerobic digestion, because composting is less resource efficient. After an initial examination of current technology for anaerobic digestion four Master's Theses were initiated on that subject, three of which were completed within the frame of TOSUWAMA:

1. **Drying of food waste**. The study shows that food waste should be dried with microwaves, if at all. Drying using hot air requires much more energy, especially if the air is heated to a high temperature.

2. **Pre-treatment of organic waste before digestion**. According to the study pre-treatment with a screw press has a far greater environmental impact than conventional pre-treatments as the screw press uses more electricity. LCA results show that, from a systems perspective, anaerobic digestion of bio- and fibre sludge causes approximately the same amount of global warming, acidification and eutrophication as does the incineration of the sludge.

3. **Analysis of energy efficiency in the Svensk Växtkraft biogas plant in Västerås**. During normal operation the biogas plant consumes 64 kWh of electricity and 97 kWh of heat per tonne of waste treated. The heat generated is used primarily in the sanitation treatment that the waste undergoes before it reaches the digestion chamber. The model developed by Liljenstam Cerruto (2011) indicates that the use of process heat can be reduced by 44 per cent if the waste is pasteurized at 55 °C for ten hours, instead of as now at 70 °C for an hour.

Treatment of Textile Waste

In Sweden, we consume 15 kg textiles per person and year. Textiles account for only about 0.25 per cent of the municipal waste treated in Sweden; however, since the textiles manufacturing generates approximately 15 kg of carbon dioxide for each kilo of virgin fabric, Swedish textile consumption is responsible for 2-3 per cent of the global warming caused by Swedish consumption (Palm 2011).

Compared with incinerating textile waste for energy recovery, the recycling and reuse of textiles reduce greenhouse gas emissions significantly. If old textiles are cut up and reassembled into new textile products using the so-called remake technology, approximately 6 kg of carbon dioxide equivalents per kg textile will be saved. In the lyocell process a solvent is used to separate cotton and polyester to make new fibres for textiles. This also saves approximately 6 kg of carbon dioxide equivalents per kg textile. The Patagonia process, which is a process for recycling polyester, saves about 3 kg of carbon dioxide equivalents per kg textile. The three recycling techniques are preferably used in sequence, since they in part target different parts of the textile waste flow. If applied in sequence to the entire Swedish flow of textile waste, which is 141 kilotons per year, 1.2 million tonnes of carbon dioxide equivalents per year can be saved compared to incineration of it all.

Recovery and recycling of textiles is primarily restricted by economic factors. Virgin fabrics are inexpensive compared to reused and recycled textiles. That is partly because the former are

produced in low-cost countries while collecting for reuse takes place in Sweden, where the cost of labour is higher. Another reason is that environmental costs are not included in the textile price. Due to poor profitability there is no large-scale recycling of textiles in Sweden today.

Political decisions, or voluntary commitments from producers and retailers, are needed to make the management of textile waste more sustainable. When policies for this area are developed they should take into account the more or less informal reuse already underway when clothes are donated to non-profit organizations and second-hand stores, and when clothing is passed on to friends or to younger siblings.

There is also a need for new cost-effective and viable recycling methods for textiles that cannot be reused. With the exception of polyester recycling in certain niches, recycled textiles are currently only used in low-grade products. A particular challenge is to develop technologies for separating mixed fibre flows.

Conventional materials should also be largely replaced with more durable ones. New textiles should be adapted for reuse or recycling, depending on their expected aesthetic and technical life expectancy.

TOSUWAMA publications (see www.sustainablewaste.info)

Back E. (2012) Modeling of pretreatment technologies for anaerobic digestion of organic waste. Master's Thesis. Uppsala University.

Liljestam Cerruto J. (2011) Energy analysis of Svensk Växtkraft's biogas plant in Västerås. Master's Thesis 2011:10. Swedish University of Agricultural Sciences, Uppsala.

Nilsson M. (2011) Simulation of food waste drying – A comparison of the energy demand in microwave and convection drying. Master's Thesis. Karlstads University.

Palm D. (2011) Improved waste management of textiles. Report B1976. IVL Swedish Environmental Research Institute, Stockholm.

Miliutenko S, Björklund A, Carlsson A. (2012a) Opportunities for environmentally improved asphalt recycling in Sweden. Supporting information. TRITA-INFRA-FMS 2012:1. Royal Institute of Technology, Stockholm.

Miliutenko S, Björklund A, Carlsson A. (2012b) Opportunities for environmentally improved asphalt recycling: The example of Sweden (manuscript).

Zamani B. (2011) Carbon footprint and energy use of textile recycling techniques. Chalmers University of Technology, Gothenburg.

Additional Literature

Carlsson A, Hemström K, Edborg P, Stenmarck Å, Sörme L. (2011) Kartläggning av mängder och flöden av textilavfall. SMED report 46 Swedish Environmental Emissions Data.

EAPA (2005) Industry Statement on the recycling of asphalt mixes and use of waste of asphalt pavements. European Asphalt Pavement Association, Brussels.

Towards the Future!

Waste-management systems are complex. There are many different waste fractions and sources of waste. Society also has established a range of goals for these systems. We want to reduce waste, increase recycling, use resources efficiently, make waste an integral part of a sustainable energy system and do all this in a cost effective way. The waste-management system should be easy to use as well. Because we want to achieve so much we will probably find it necessary to implement many different policy instruments that can complement each other. No single instrument can solve all problems.

New Policy Instruments are Necessary

The inventory of policy instrument proposals we instigated at the start of the research program (see Introduction) shows that many new ideas are in circulation. If we were to do the process over again today, we would probably get even more suggestions and probably new angles on old ideas as well. A number of instruments that have been evaluated in the program have been shown to have a clear effect, and are therefore interesting to investigate further. These are:

Obligation to recycle recyclable materials. There is currently a ban on landfilling of organic and combustible materials. The next step in line with the waste hierarchy can be to introduce a ban on incineration and landfilling of certain recyclable materials, that is to say, explicit making recycling mandatory. If recycling does not lead to a large loss of materials, and if the recycled materials replace virgin materials of a similar kind, this regulatory control has a great potential to reduce environmental impact. Our evaluations indicate that costs will increase, but not unreasonably so compared to the environmental gain. Further studies are necessary to identify which materials are of interest to target first, and to what extent. An important step is to define recyclable. Care should be taken so that the recycling does not lead to an increased risk of spreading hazardous substances compared to using virgin materials.

Weight-based waste-collection fee for households are already in force in many municipalities and this generally leads to a reduction in the amount of unsorted household waste and increased recycling. The effects are not huge but there are still environmental gains to be made. However, there is a risk associated with weight-based waste tariffs – they can lead to increased illegal disposal, such as combustion of waste in small house boilers and bonfires. Since the emission of pollutants from these may be a thousand times higher than from controlled waste incineration, it is important to make sure that this does not occur when weight-based waste-collection fees are introduced.

“Advertising, Yes Please!” and other waste prevention measures. This instrument means that unaddressed direct mail can only be distributed to households who display this message. Compared to the current situation where it is necessary to display the “Advertising, No Thanks!” message to avoid direct advertising, this will lead to a decrease in the amount of household paper waste. This is one example of a waste prevention measure, but there are many more (Ljunggren Söderman et al. 2011). The benefit of waste prevention is not just that there will be less waste, but above all that the environmental impact of manufacturing and the production of raw materials will be reduced.

Differentiated VAT. Our evaluation shows that a reduction in VAT on services reduces environmental impact, without affecting growth to any great extent. Environmental gains were not large in the case studied, but it would be interesting to explore how greater or more specific changes in VAT can be designed, and also how they would affect other factors such as employment.

Negative labelling of products with hazardous substances. Waste prevention is not just about reducing the amount of waste, but also about reducing the dangers inherent in waste. The reduced use of hazardous chemicals can be part of waste prevention. Labelling is already obligatory for chemical products but not for consumer goods that contain hazardous substances. For example, when consumers buy clothing or toys they are not informed if the product they purchase contains hazardous chemicals. A mandatory labelling would give consumers that information, influencing their choices and thereby reducing the hazards inherent in both products and waste.

Mandatory requirements, or support, for waste minimization in companies. Today many businesses work actively to promote material efficiency and with other types of waste minimization, but more can probably be done in this respect. For this reason a policy instrument that requires companies to work more on waste minimization, or that supports such efforts, could be relevant. It could be part of the conditions given in permits for factories and other production plants, or implemented as an addendum to the regulatory framework governing waste disposal.

Improved surveillance by authorities. Many players have pointed out that improved monitoring in the waste disposal sector may be an effective policy instrument.

Information is an essential policy instrument, although insufficient in itself. On its own it has limited impact but in conjunction with other instruments it may be vital. The way the information is presented may depend on whether the aim is to influence values and beliefs or to inform about, for example, a new collection system. Thus it is important to consider both how the information is designed and when it should be distributed.

Additional Ideas for Policy Instruments

In addition to the instruments we have evaluated in the program, we have found several new proposals that would require further study. Here are just some of these:

A substantial, but competitively neutral, commodity or materials tax. In Sweden today there are raw-material taxes on gravel and hydrocarbon deposits used as fuel. In a sustainable society, it may be wise to broaden the tax base to cover more commodities and raw materials. The structuring of such taxes is, however, not easy and must be investigated further.

A substantial tax on hazardous substances. Very dangerous substances should be banned by society. But there will be a large number of substances that we do not want, or are able to ban but that we want to reduce the use of. Then it may be wise to subject them to taxes.

Deposit systems and recycling bonuses. Deposit systems can be very efficient for collecting used products. They should probably be used more. An alternative can sometimes be to give a bonus or premium when discarded products are deposited, even if no deposit has been paid. A scrapping

premium for cars is one such example. This may be appropriate if improper waste disposal leads to substantial environmental problems.

Expanded landfill tax. Today many waste fractions are exempt from landfill tax. These exemptions are given when there are no other suitable options. But these exceptions mean that there is little incentive to waste prevention or to the development of alternative waste-management options. It might be a good idea to introduce a modest landfill tax for such waste as well. This tax should ideally reflect the particular environmental problems caused by landfilling.

Requirements for storage of non-recyclable plastics. When plastics are incinerated, large amounts of fossil carbon dioxide are emitted and contribute to climate change. From an environmental perspective, it is generally best if plastics can be recycled, but if that is not possible then it is better from a climate perspective to store plastics than to incinerate them. However, this is not permitted because of landfill bans on combustible waste. A temporary storage of non-recyclable plastics is the fastest way to reduce carbon emissions from the waste-management sector today.

Policy instruments to reduce recycling transaction costs. In the smaller recycling markets it can be expensive for sellers and buyers to find each other and make agreements. Instruments that can facilitate this type of exchange include various quality assurance schemes and the development and implementation of virtual marketplaces at Internet.

Support for repair services. The Swedish tax system today includes tax deductions for household services and home renovation and extensions. One suggestion is to develop a similar system for services associated with the repair of products.

Governance for Waste Prevention – Three Models

If the objective is to prevent waste in the first place, and not only to streamline waste management, policy instruments must be designed so that they not only target waste system operators but also producers and consumers. What instruments appropriate to this end depends on how the future unfolds, and how we want it to unfold.

One way of discussing this is to start with three different models for future governance. We have chosen to call them network society; strong state; and market solutions (see Figure 9). In the “market solutions” national authorities do not interfere much. Instead, there is a strong belief in market solutions and technological development. In the “network society”, there is also little control from national authorities. Instead, the society is organized from below with a variety of solutions at various levels. In the “strong state” model, finally, the control from national authorities is extensive and the society tends toward reduced consumption. These three models tell us nothing about how the future will be, or should be; they are three conceptual models that illustrate different types of control and behaviour among social actors. They can be used to show that different instruments may be more or less effective depending on the societal settings. Instruments with different mechanisms are needed, depending on who is in control, and in what way and to what extent they are able to govern the development.

Figure 9. Three models for possible future governance.

Through discussing what instruments are feasible in these model societies, or make these societies possible, we can present three matching sets of policy instruments that complement the instruments we assessed in TOSUWAMA. Note that these sets of instruments do not exclude one another. When it comes to the practical implementation of instruments, it is probably better to strive for diversity. This can be achieved by putting together different components from the different packages.

Examples of Complementary Instruments in the Market Solutions Model

Extraction rights that limit the extraction of non-renewable natural resources for materials production. Such a system can function the same way as the emissions trading scheme for carbon dioxide. It introduces a ceiling on how much of a natural resource may be extracted per year. Those who are willing to pay the most for the right to extract natural resources get to buy that right. The ceiling can then be gradually lowered.

Steering towards consumption patterns that generate less waste. Bisaillon et al. (2009) write that an increased consumption of luxury goods may generate less waste per consumed unit of currency. This often also applies when consumption is shifted from goods towards time-consuming services. But consuming luxury goods can also be problematic due to other environmental consequences. For example, meat is more expensive to eat than beans but not as energy efficient and gold for the production of jewellery is extracted in a way that causes environmental degradation and human rights abuse.

Function Sales is another strategy that can lead to a consumption of durable goods of high quality, so that people do not have to buy new items as frequently. It can include things like buying services "a washing machine that works for ten years." One way to make durable products last longer can be to stimulate repair through grants.

Centre for Resource Efficiency. The establishment of a dedicated centre can enrich knowledge on how materials and other natural resources can be used more efficient in order to reduce waste. Resource efficiency is often seen as the key to combining sustainable development with high growth. For example, see "Resource Efficient Europe" a flagship initiative of the Europe 2020 strategy for

smart, sustainable and inclusive growth. To achieve this more research, development and dissemination are needed in the areas of green technology, efficient recycling, and energy efficiency.

Voluntary labelling can be a way for companies to create an environmental profile and promote goodwill. The instrument itself is not new, the Swedish KRAV label is a good example, but it is conceivable that a new form of labelling could be introduced that shows the amount of waste created when a good or service is produced and how hazardous this waste is. Today, this is difficult for consumers to find out. The consumer sees only what is consumed. In the consumption of services it can be particularly difficult to understand the type and quantity of waste associated with, for example, a visit to the cinema.

Examples of Complementary Instruments in the Network Society Model

Barter is the trading of goods and services without the use of money. It has similar effects as the use of alternative, complementary currencies.

Borrowing and renting instead of owning means that fewer things are needed in the community because households do not need to own things they rarely use. For example, many household tools such as sewing machines, power drills and floor sanders are seldom used. Joint ownership is also an option, as in car pools. Tools, extra chairs for parties and much more can be jointly owned within, for example, a residential area.

Examples of Complementary Instruments in the Strong State Model

Taxes on natural resources or material can contribute to making the use of materials more efficient. Sweden already has a commodity tax on natural gravel and an energy tax on fossil fuels. Taxes on resources and materials can be designed in a number of different ways. They can be broad taxes that cover a wide range of materials or specific taxes for specific materials.

Bans on certain goods because they are seen as unnecessary or because they use too much of a particular substance. A few substances, such as PCBs and mercury, are already banned. In many parts of the world there is a ban on plastic bags.

Sustainable economy without growth is not an instrument or strategy in itself, but it can be a goal to be achieved by introducing, for example, reduced working hours and green public procurement.

Conclusions

Among the instruments that we have investigated in the research programme TOSUWAMA, there are those that can greatly affect how waste is managed. This is perhaps especially important in regard to recycling and weight-based waste tariffs. However, none of the instruments, as far as we could see, significantly reduces the quantity waste. Among the new ideas for instruments are a couple that may lead to increased material efficiency and reduced waste. Our results nevertheless indicate that there is need for more innovations and new ideas in this area.

Waste volumes in the different scenarios vary considerably (see the section The Quantity of Waste). This is partly because the economic growth varies between the scenarios, but also due to differences in consumption patterns and technological development. Perhaps it is possible to reduce the waste quantity through policy instruments that affect consumption patterns and lifestyles and/or that stimulate the technological development of material-efficient systems and processes. Such instruments would then probably generate environmental benefits far beyond the waste-management system.

TOSUWAMA publications (see www.sustainablewaste.info)

Bisaillon M, Finnveden G, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2009) Nya styrmedel inom avfallsområdet? TRITA-INFRA-FMS 2009:7. Royal Institute of Technology, Stockholm.

Dreborg K-H, Tyskeng S. (2008) Framtida förutsättningar för en hållbar avfallshantering – Övergripande omvärldsscenarier samt referensscenario. TRITA-INFRA-FMS 2008:6. Royal Institute of Technology, Stockholm.

Finnveden G, Ekvall T, Arushanyan Y, Bisaillon M, Henriksson G, Gunnarsson Östling U, Ljunggren Söderman M, Sahlin J, Stenmarck Å, Sundberg J, Sundqvist J-O, Svenfelt Å, Söderholm P, Björklund A, Eriksson O, Forsfält T, Guath M. (2013) Policy Instruments towards a Sustainable Waste Management. Sustainability 5(3): 841-881.

Finnveden G, Bisaillon M, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2012) Developing and evaluating policy instruments for sustainable waste management. International Journal of Environment and Sustainable Development 11:19-31.

Finnveden G, Björklund A, Carlsson Reich M, Eriksson O, Sörbom A. (2007) Flexible and robust strategies for waste management in Sweden. Waste Management 27(8): S1-S8.

Finnveden G, Bisaillon M, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2011) Developing and Evaluating New Policy Instruments for Sustainable Waste management. Presented at VIth Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems, September 25-29, 2011, Dubrovnik, Croatia.

Finnveden G, Bisaillon M, Noring M, Stenmarck Å, Sundberg J, Sundqvist J-O, Tyskeng S. (2010) New policy instruments for a sustainable waste management? In Proceedings of Global Waste management Symposium, 3-6 Oktober 2010, San Antonio, Texas.

Additional Literature

Ljunggren Söderman M, Davidsson H, Jensen C, Palm D, Stenmarck Å. (2011) Goda exempel på förebyggande av avfall. Report U2011:05. Avfall Sverige – Swedish Waste Management, Malmö.

Final Words from the Coordinator

As we now reached the end of the TOSUWAMA programme, we are in many ways wiser and more experienced than when we started. We have struggled with interdisciplinary communication and with large models. This has influenced our thinking and our approach to both policy instruments and research beyond the clear and concrete results given by our analysis. This concluding section includes three personal reflections from the programme manager Tomas Ekvall.

Tailor the Instrument to the Material

The policy instruments that are appropriate and their effectiveness depend in part on the type of material in question. For some materials the recycling markets are well-established and global. This applies, for example, to newsprint and several metals (see section Markets for Recycled Materials). For other materials, such as textiles, such markets are not yet well established. This means that the effectiveness of different instruments for increasing the recycling of various materials will probably vary. The same goes for increasing material efficiency and thereby reducing the amount of waste (see Table 2).

For materials that have a well-established, international recycling market, it is not very important how much recycled material we use in Sweden. In these cases a national system of recycling certificates and taxes on virgin raw materials are not effective; they are likely to lead to the recycled material being redirected to Sweden instead of being used in other countries (see Markets for Recycled Materials).

What is important is instead the total amount of materials we use and how much we collect for recycling. The recycled materials we collect will mainly displace virgin materials in the international market – as long as the price is right. Instruments that can lead to increased collection of recyclable materials include extended producer responsibility, weight-based waste-collection fees, and the mandatory recovery of recyclable materials. In order to reduce the overall use of materials the cost of these materials may be increased, for example by a tax on virgin and recycled materials used in Sweden (cf. the section Stakeholders and Organizations).

For materials that lack an established recycling market, the authorities can help to establish systems for communication between buyers and sellers of recycled materials. Instruments can also help establish a market by encouraging or forcing an increased use of recycled materials in Sweden, for example, by implementing recycling certificates or a tax on virgin materials. Such instruments will probably also contribute to increased material efficiency, because they make the use of materials more expensive in Sweden.

Table 2: The appropriate focus of policy instruments depends on whether the material has an established international recycling market or not.

For materials that… We need to achieve…	…have an established recycling market	… do not have an established recycling market
… increased material recovery	Increase collection	Increase use, collection and brokerage
… increased material efficiency	Raise material cost	Raise cost of virgin material

Numbers and Insights

We have evaluated instruments using a combination of quantitative models and qualitative narrative analyses. The qualitative analyses provide us with insights into what is important and how things fit together. They are just as important as the results from the quantitative calculations.

The quantitative calculation results should also not be taken at face value. Most of our calculations were made using the models described in the introduction: the EMEC economic model, the techno-economic waste management model NatWaste and the life cycle assessment model SWEA. These are comprehensive and powerful models, but they are still based, as are all models, on the simplification of a complex reality. Therefore it is necessary to interpret the results: to carefully consider how well the numbers reflect reality and to what extent they have been affected by the simplifications in the models. Qualitative discussions and analyses are needed also for this interpretation. In the end the most important thing we get out of the models is not the numbers, but valuable insights about what is essential in the systems we study and how these things are connected.

Interdisciplinary Research: Difficult but Necessary

As waste researcher Per E.O. Berg observed at our last regular reference group meeting: interdisciplinary research is difficult. Not only do the TOSUWAMA researchers have different background knowledge, but they also use a different scientific jargon. We even have different views on what our research is good for, and therefore different views on what comprises good research.

At the same time interdisciplinary research is necessary when developing ideas for policy instruments and assessing them on the grounds of science and social science. If left to themselves, economists, engineers, behavioural and environmental scientists can only explain a small part of the total picture. To produce a comprehensive and coherent assessment it is also not enough to be working alongside one another. In order to be able to draw conclusions from the overall results we need to understand each other's conclusions, and to understand each other we must work together.

In the TOSUWAMA research programme we have developed and implemented a new way of collaborating across multiple disciplines (see Figure 10). The initiative for the program was taken by a group of systems analysts used to interdisciplinary research with LCA and other system studies. To

add scientific depth to the research, we attached the team to specialists from the various disciplines, economics, psychology, and anthropology. However, each project in the research programme included at least one life cycle analyst as partner to the specialists. The idea was that by participating actively in the project this person would become an interpreter or bridge between disciplines. The life cycle analyst should help the specialists plan the research to make it relevant to the questions we wanted answered, and, in addition, assist with the interpretation of the results of their project.

Structuring the project in this way compelled the specialists and their interpreters to meet the challenge of understanding one another. For this to work the researchers must share a common interest in attempting to establish reciprocal understanding. The success of the collaboration depended on several factors. The likelihood of the collaboration being fruitful increases if the researchers' areas of background knowledge overlap, if their research cultures are similar, if there is a common interest in the research issues, and if the specialists are also accustomed to interdisciplinary collaboration.

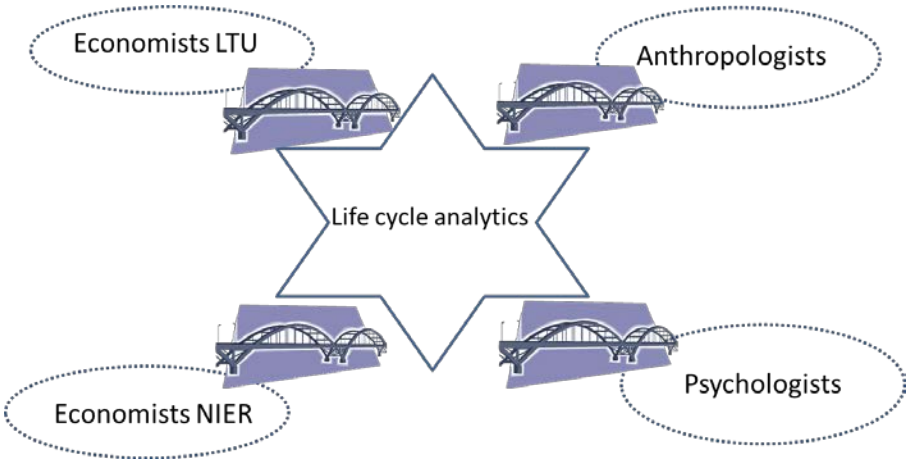


Figure 10. Illustration of the interdisciplinary cooperation within programme projects between LCA specialists, economists from Luleå University of Technology (Lutu), the Swedish National Institute of Economic Research (NIER) and anthropologists and psychologists.

Our work across disciplines not only involved collaboration within projects, but also collaboration between different projects: the engineers have developed input data for the EMEC economic model that, in turn, fed the results back to the models of the engineers. Anthropologists and psychologists have collaborated on case studies and around common conclusions. One of the challenges of this way of working is that it is highly susceptible to unforeseen events that cause delays. A delay in one research team is likely to affect other parts of the research programme. This should be taken into account at the planning stage.

Despite the challenges discussed here, the final results of the collaborative efforts of the TOSUWAMA programme have been good. We reached conclusions that rest on a broad foundation. In addition, we developed powerful packages of computational models and methods that can be used for new assessment in the future.

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