Towards Sustainable Waste Management

Programme leader

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Summary

This research programme aims at identifying policy instruments and other strategic decisions that contribute to the development of a more sustainable waste management. For this purpose, we investigate environmental, economic, cultural and social aspects of the waste management system, focusing on waste prevention, product reuse, and material recycling, including biological treatment. Economists, ethnologists and an environmental psychologist will carry through the studies in co-operation with systems analysts and futurologists.

We survey existing and potential policy instruments and formulate promising alternatives. We assess these by combining and expanding on existing models, methodology, and databases from economics, waste systems analysis and environmental systems analysis: partial and general equilibrium models, life cycle assessment, substance and material flow analysis, etc.

We investigate systems for source separation and collection with an aim to develop knowledge that is needed to adapt these systems to consumers, organisations and companies. These investigations are carried through with quantitative methods from environmental psychology as well as qualitative cultural analysis. We also investigate the processes of the recycling industry, aiming to improve their environmental performance. We develop future scenarios to generate background data for the assessments of policy instruments and to illustrate threats and solutions to the sustainability of waste management.

Content

1. Purpose and aim

The purpose of this research programme is to identify policy instruments and other strategic decisions that contribute to the development of a more sustainable waste management. A more sustainable waste management system is a system that contributes to increasing efficiency in the use of natural resources, and to decreasing environmental burdens. Environmental improvements within Sweden should not be offset by unwanted consequences in other countries. To be sustainable, the waste management must also be affordable and widely accepted by the public as well as by key companies and organisations.

For this purpose, we investigate environmental, economic, cultural and social aspects of the waste management system, focusing on the upper end of the waste hierarchy: waste reduction, product reuse, and material recycling (incl. biological treatment). We combine and expand on existing models and methodology from different disciplines to assess existing and potential policy instruments in important areas such as waste prevention, source separation, etc. The new knowledge, as well as previously existing knowledge, is integrated by systems analysts and utilised to generate scenarios that describe how a more sustainable waste management can be achieved. The models and methodology that result from the programme will be documented in a way that facilitates their subsequent use in follow-up studies and future research efforts.

2. State of the art

Swedish waste management has undergone rapid changes in the past 10 years. Deposition at landfill has decreased to less than half, and only 9% of the household waste was deposited in 2004 (RVF 2005). Meanwhile, material recycling has increased rapidly during the 1990s. A third of the material in Swedish household waste is now recycled, which is a large share compared to other countries. In addition, biological treatment has increased to 10% (RVF 2005). Waste incineration with energy recovery currently expands forcefully. As a result of bans on landfilling that have been implemented during the past few years, the capacity for waste incineration will approximately double during the first decade of this century (Sahlin et al. 2004). A large number of life cycle assessments (LCAs) have been carried through in this area. They indicate that the waste hierarchy is valid, as a rule of thumb, for the environmental ranking of waste management options (e.g., Björklund & Finnveden 2005). This indicates that the changes that have occurred are environmentally beneficial. In addition, the environmental performance of landfilling, waste incineration, and biological treatment has improved significantly during the past 20-30 years as a result of technological development spurred by environmental pressure from the public opinion and authorities.

The rapid changes have put a significant strain on the waste management system, however. The extended producer responsibility has been repeatedly questioned. Furthermore, the quantity of

waste continues to increase by 2-3% each year in spite of the national environmental target stating that the total quantity of waste should not be larger this year than 1994 (EPA 2005a). This is serious because waste management is bound to affect the environment and, probably even more important, because the environment is affected by the production of all material that ends up as waste. In spite of successful recycling schemes, the waste quantities remaining after materials recycling have been relatively constant since the beginning of the 1990s. To avoid a future increase in landfill and incineration, the rate of collection for recycling needs to increase further and the exponential growth of waste flows needs to be restrained. This requires that not only the waste management but also the consumption develop in a sustainable direction. The path towards the political targets in this area is unclear, and much of the knowledge that is required to take us there is missing.

There is an obvious coupling between waste quantities and economic growth, since economic growth to a large extent is a function of the amount of materials passing through our society. However, different sectors in society have different waste intensity, and technological development, policy measures, etc. affect the waste intensities. Bruvoll & Ibenholt (1997) quantify the future waste type *j* in sector *i* in year *t* using a simple formula:

$$W_{ij}(t) = W_{ij}(t_0) \cdot U_{ij}(t) \cdot d_{ij}(t),$$

where $W_{ij}(t_0)$ is the corresponding waste flow at the base year, and $U_{ij}(t)$ is an index for the explanatory variable, either production or material input in sector *i* generated by a macroeconomic model. Finally, $d_{ij}(t)$ allows for an exogenous shift in the waste flow due to, e.g., political measures. Andersen et al. (1999) adopt a similar method, although expressed by a slightly more complex equation. These methods have recently been tested in a master thesis at Chalmers (Svensson 2005). We will also benefit from knowledge gained at case studies on future waste quantities performed by Profu (e.g., Profu 2001) and others (e.g., Daskalopoulos et al. 1998, Chen & Chang 2000, Karavezyris et al. 2002, Navarro-Esbri et al. 2002, and Ibenholt 2003).

Effective source separation and recycling schemes require active participation of a large share of the population. The time spent on source separation in households has been identified as the dominating cost in several cost-benefit analyses (CBAs) of recycling (e.g., Radetzki 1999), challenging the sustainability of such schemes. To become truly sustainable they need to be perceived as meaningful by consumers, companies and organisations. Source separation also needs to be simple and rapid to carry out in practice. At the same time, the waste collection must be safe, its economic cost must be reasonable and the cost must be covered in a sustainable manner. Significant potential for environmental improvements exists in some recycling processes, possibly because they are relatively new and have not experienced the same external pressure as, for example, incineration and landfills. LCAs and similar environmental assessments are based on data that reflect current performance and might under-estimate the long-term environmental benefits of recycling, weakening the environmental arguments for recycling of materials.

Waste management is affected by policy instruments of various kinds: legislative (landfill bans, emission limits, etc.), economic (taxes, differentiated waste collection fees, etc.), information, and physical improvements (e.g., curbside collection). The recent commission on waste-incineration tax recently found that no decision-support tools were available that could model possible outcomes and evaluate the related environmental impacts of such policy instruments. It is even more difficult to analyse how the different policy instruments interact. A policy instrument that is well devised, logical and effective in theory might still be ineffective when applied in an institutional context. To be effective, the policy instrument has to target the

organisations and individuals that, in turn, affect the waste management. In addition, the worldviews, incentives, aims and values etc., held by key-persons at public institutions and private companies within the waste management sector, constitute an important precondition for the function of the policy instruments.

Policy instruments aiming at waste prevention and recycling have been reviewed by, e.g., Dette & Jülich (1999). For the purpose of this programme, we need to compile and add to these reviews on a broader basis. The study on taxation of natural resources etc. published by the Swedish Environmental Protection Agency (EPA; Söderholm 2004) gave insights into the formulation of Swedish policy instruments in the waste management area. Additional understanding resulted from the recent commission on waste-incineration tax (Department of Finance 2005). We were actively involved in both of these projects. The proposed research group has also been involved in many of the Swedish LCAs and CBAs in this area (see enclosed CVs). They have resulted in insights, databases and models that provide a good starting point for our programme (Ekvall & Finnveden 2000, Björklund & Finnveden 2005). Through active participation in the International Expert Group on life Cycle Assessment for Integrated Waste Management (IEG), we also have access to findings from studies in other countries.

It is often assumed that an increase in collection for recycling is effective for increasing the total recycling rate. However, Ekvall (2000) proposes that a local or national increase in collection for recycling is likely to result in a reduction in the collection elsewhere, and that the most effective way to increase total recycling might be to increase the use of recycled material. If this is correct, policy instruments aiming at increased recycling should focus on stimulating the use of recycled material and not so much on source separation and collection of separated waste fractions. This illustrates the importance of analysing the existing markets for recycled materials.

Systems for source separation have been investigated for the past 15 years (Berg 1993). Recent studies have been made on source separation and collection from households as well as workplaces (e.g., Sörbom 2003, Schmidt et al. 2004). Quantitative studies have shown that people generally are positive towards source separation (Sörbom 2003). When attitudes are compared to behaviour, it is obvious that a gap exists between what people think and what many actually do (Rathje & Murphy 2001).

Lack of information can be a barrier to participation in source separation and other pro-environmental actions. It is not always obvious to an individual how to act in the best manner, even if he or she does express an environmental concern. Even with common problems such as reducing energy consumption or sustainable waste managing, many people do not know which conservation actions are most effective or what alternative recycling does exist. Environmental information is a policy instrument that is commonly used to influence people to act more environmentally benign. However, information campaigns are not always successful in changing attitudes or behavior. The link between new information, attitude and behavior is sometimes weak or absent. This vagueness could be caused by several factors. For instance, not everyone is highly concerned about the environment. Conflicting motives is something that people constantly struggle with in their everyday life. Furthermore, not every one is motivated to pay attention to environmental information.

It has been suggested that the way information is presented and how it is received can determine whether information has the intended effect or not (Gardner & Stern, 1996). For this reason, it is important to investigate under what conditions information is most effective; when and how information can make a difference. This is especially true for information aiming at environmental protection, because the connection between own behavior and its environmental effects can be impossible to discern solely from personal experience. It is essential that information aiming at persuading individuals to change their behavior in a more environmentally

benign direction be designed such that people pay attention to it, that it makes sense and that it is credible. Information should be personally relevant to people.

The participation in source separation schemes is also affected by cultural perspectives linked to questions on waste and/or value, order and disorder, and on cultural decomposition. Such issues are explored by anthropologists, ethnologists, and sociologists (e.g., Thompson 1979). Attitudes versus behaviour in dealing with garbage have been studied in the so-called field of "garbageology", an archaeology of the contemporary society (e.g., Mayne & Murray 2001). A project at the department of European Ethnology in Lund applies Cultural theory and Cultural analysis to study processes of cultural attrition. At the same department, several projects connected to waste and sustainability are carried out by human ecologists (Hornborg 2001).

During most of the 1990s, the Waste Research Council (AFR and, subsequently, AFN) funded a major waste-research programme in Sweden. The strong focus of the waste research to this programme allowed efficient communication between research groups and between researchers and decision-makers. The programme also allowed for capacity building that resulted in, for example, expertise on LCA of waste management that could compete with the leading international experts. In parallel to this programme, the REFORSK foundation financed many shorter research projects.

After the end of AFN and REFORSK, Swedish research on waste management declined. The research still continues (e.g., Mattsson 2004, Olofsson 2004, Assefa 2005, Klang 2005, Moberg 2006) but it is dispersed and uncoordinated, and it has become difficult to initiate new research projects. Through this research programme EPA makes it possible to vitalise and co-ordinate at least part of this research.

Several of the ongoing research programmes funded by EPA also includes research that is relevant to this programme:

- SHARP, with its focus on sustainable households, aims at the design of effective environmental policy instruments and also investigates households' responses to policy instruments in, for example, the waste management area.
- FLIPP, with its focus on integrated product policy, has a clear life cycle perspective. This is an important perspective also in our programme.
- MIST, with its focus on strategic environmental assessment, includes a project on the energy and waste management sectors.

We can utilise the relevant research results effectively because our research group includes participants in each of these ongoing programmes and even the co-ordinator of SHARP. However, our programme is unique in the sense that it integrates technical, environmental, economic, cultural, and social knowledge of the entire waste-management system. This facilitates a comprehensive assessment of policy instruments in this area as well as an analysis of how different policy instruments interact. A specific feature of our programme is the analysis of policy instruments to reduce waste quantities and increase recycling.

We have understood that EPA plans to establish a separate research programme dealing with organic hazardous substances in waste. This issue will be touched upon only briefly in our programme.

3. Relevance to society

The Swedish environmental objective "A good built environment" calls for waste prevention, high recovery of resources in waste, while minimising impacts on health and the environment (EPA 2005a). Decoupling of waste quantities and economy is a target not only for the national

policy but also in the European Union (EC 2005a, EC 2005b). The EPA recently published a national waste plan, where several prioritised areas for the future development of Swedish waste management are identified (EPA 2005b):

- Implement and assess existing policy instruments. It is important, EPA states, to implement the waste incineration tax and the general rules of the environmental legislation. It is also important to investigate whether existing policy instruments have the intended effects.
- Reduce the environmental hazard and the total quantity of waste. This involves further development of products and chemicals.
- Increase the knowledge on the environmental impact of hazardous substances. There is a significant lack of knowledge on the long-term impacts of diffuse emissions of hazardous substances from landfills, recycling and biological treatment.
- Source separation needs to be simple for households. The collection systems of municipalities and producers need further development to ensure the confidence and continued participation of households in source separation schemes.
- Participate in the EU efforts on waste management. Sweden needs a clear strategy on how to run waste management issues in the EU and take active part in the development of new directives.

In the call for a research program on sustainable waste management, EPA stresses the need for interdisciplinary research in this field. They specifically call for the involvement of behavioural scientists etc. to add their expertise to the existing expertise on the technological and scientific aspects of waste management. The EPA indicates three important areas for research:

- Policy instruments for sustainable waste management. This area includes the development and assessment of informative, economic and legal policy instruments and combinations of such instruments. These should be efficient for increased waste reduction and recycling, including biological treatment, and contribute to the reduction of the environmental impact of chemicals. This area also includes the development of tools for the assessment of policy instruments.
- Systems for source separation and collection of waste. This area includes research on consumer behaviour and research on the acceptance of systems for source separation and collection. It also includes research on the attitudes towards waste minimisation and reuse and the impact of information.
- Systems perspectives, prognoses and scenarios for sustainable flows of material and waste. This area includes analyses of inflow, storage, and outflow of materials in the society. It also includes the assessment of economic, social and ecological sustainability of present and potential systems for waste management. The assessments should have a broad systems perspective. They should take into account the relation between sustainable economic growth and the need for reducing the quantity and environmental hazard of waste.

In response to this call and the state of the art, as described above, we have planned a programme, Towards Sustainable Waste Management (TOSUWAMA), that includes 10 research projects:

1. Policy instrument formulation: formulates new informative, economic, legislative and/or physical policy instruments and new combinations of such instruments aiming towards a more sustainable solid waste management.
2. Economic modelling for assessment of policy instruments: refines and links a systems engineering model for national waste management, NatWaste, and an applied general equilibrium economic model, Environmental Medium term EConomic model (EMEC), and applies the combination of models to analyse how existing and/or new policy instruments affect the waste flows and the economy. This project contributes to investigating the effects of the policy instruments and the economic sustainability of present and potential systems for waste management.

3. Environmental assessment of policy instruments: applies LCA and substance flow analysis to assess proposed waste policy instruments from a life cycle perspective. This project contributes to investigating the environmental effects of the policy instruments and the ecological sustainability of present and potential systems for waste management. It results in knowledge on how to reduce the environmental hazard of waste, and how to deal with hazardous substances in the waste.
4. Institutional aspects and the waste-incineration tax: investigates the effects of the waste incineration tax that is included in the present national budget and compares it to a tax that targets the fossil content of the waste. The project contributes to investigating the effects of this particular policy instrument, and discusses the significance of institutional aspects for the effect of policy instrument.
5. Evaluating design and impact of environmental information: applies quantitative methods of environmental psychology to investigate how environmental information can be developed and designed in order to increase people's readiness to take part in source separation schemes. Such knowledge is important in the further development of systems for source separation and collection.
6. Sorting things out - considering cultural categories of waste: applies qualitative cultural analysis to investigate what is required to make a source separation scheme easy to understand and take part in. This is also important in the continuing development of systems for source separation and collection.
7. Future waste quantities: develops and refines models to investigate how the quantity of waste develops in the future, and how the trend can be affected by policy measures aiming at waste prevention. This is important to reduce the total quantity of waste.
8. Markets for virgin and secondary materials: develops a partial equilibrium model of the markets for virgin and recycled material. The project also applies this model to investigate how source separation schemes and policy instruments stimulating the use of recycled material affect the total recycling rate. This project contributes to investigating the effects of such policy instruments.
9. Environmentally improved recycling: investigates the potential for environmental improvements in recycling processes, obstacles to these improvements, and possible actions and decisions that might remove these obstacles. This project contributes to reducing the environmental impact and reinforcing the environmental arguments of material recycling.
10. Future-oriented synthesis: establishes common external scenarios for the programme; adds insights and knowledge generated in the various projects to insights and knowledge generated elsewhere, aiming at identifying policy instruments and other strategic decisions that contribute to the sustainable development of the waste-management system.

Each project in TOSUWAMA is designed to contribute significant pieces of information and understanding that are relevant for the purpose of sustainable development of Swedish waste management. In addition, the synthesis of the programme identifies decisions that contribute to the sustainable development of the waste-management system. This means that the programme goes further than conventional research programmes in the process of giving practical guidance to policy-makers. The research programme will provide analyses and empirical results, which can help answering many questions of direct relevance to public and private decision-makers and ultimately for environmental policy goal fulfilment. Examples of such questions include how do policy instruments aiming at sustainable waste management and sustainable consumption affect the material flows in the society? How do they affect the environmental burdens and the demand for natural resources? What policy instruments or combinations of policy instruments are effective for guiding the waste management system in a sustainable direction? How can consumer-adapted systems for source-separation and collection be designed? How can the waste-related behaviour of consumers and producers be affected? Such knowledge will be vital for the

development of Swedish policy on waste management and also for Swedish participation in the development of EU directives.

The EPA instructions for planning the research programme stresses gender issues. Our investigations on the perception of waste, source separation, and the related information will include differences that relate to gender (see Projects 5 and 6 in the Project Annex).

TOSUWAMA will result in cross-disciplinary models that allow us to describe and predict the consequences of policy instruments more accurately and comprehensively than before. We expect the new features of such modelling, which will be useful also beyond the waste-management sector, to include the connection between the waste management system and the overall Swedish economy, and also the connection between waste management in Sweden and waste management in other countries. The models and methodology that result from the programme will be documented in a way that facilitates their subsequent use in follow-up studies and future research efforts. They will provide a necessary framework for decision support when it comes to evaluating the efficiency of existing and proposed waste policy instruments.

TOSUWAMA is not only practically but also scientifically relevant, because it is founded on established research in the area of waste management, and brings new disciplines into this area. We integrate expertise on technology, economy, environment, psychology, ethnology, and futurology into a network of waste systems analysts. The systems analysts are experts on LCA, CBA and similar methods. The introduction of LCA in policymaking as a means to modernise the existing legal framework on waste management was recently brought forward by the European Commission (EC 2005a, EC 2005b). Hence, it is strategically important for Swedish authorities to be at the forefront of this development.

4. Programme management and organisation

The programme will be lead by *Tomas Ekvall*, researcher at IVL and Associate Professor at the Department of Energy and Environment, Chalmers University of Technology. He has an extensive experience from research management: as manager of contract research projects at Chalmers Industriteknik for most of the 1990s and as research leader and head of the Division of Energy Systems Technology at Chalmers in the beginning of the 2000s. He has as a long experience as researcher and consultant in environmental systems analysis, particularly from LCA in the waste management and energy sectors. He also has experience from CBA and from dynamic modelling and other methods for futures studies. Besides co-ordinating the programme, he will lead Projects 4 and 7.

The internal and external communication of the programme will be co-ordinated by *Maria Ljunggren Söderman,* PhD and researcher at IVL. She has an extensive experience as researcher and consultant in waste-management, environmental and energy systems analysis. Her experience from communication includes the management of a Eufori project aiming at the commercialisation and broad implementation of research results funded by the Swedish Energy Administration.

The programme will have seven project leaders besides Prof. Ekvall:

Lynn Åkesson, Associate Professor and Head of the Department of European Ethnology at Lund University, has an extensive experience from studies in ethnology and from interdisciplinary collaboration. She has led several projects on culture and technology, and been a member in the Swedish Technology Foresight, initiated by the Swedish government. In this programme, she will lead Project 6.

Anna Björklund, PhD at the Division of Environmental Strategies Research at the Royal Institute of Technology is a researcher with experience from environmental systems analysis, particularly from LCA of waste management. She will lead Project 3.

Chris von Borgstede, PhD at the Psychology Department at University of Gothenburg, is an environmental psychologist with experience from studies on how social dilemmas are affected by social and personal norms on co-operation, and on structural solutions to such dilemmas. In this programme, she will lead Project 5.

Elin Eriksson, MSc and Assistant Manager of the Department for Environmental Performance at IVL, has an extensive experience as consultant and institute researcher in environmental systems analysis, particularly from LCA and CBA applied to, for example, waste management and industrial product development. She will lead Project 9.

Göran Finnveden, Associate Professor and Head of the Division of Environmental Strategies Research at the Royal Institute of Technology, is also research leader at the Department of Environmental Strategies Research of the Swedish Defence Research Agency. He also has an extensive experience as university and institute researcher from LCA of waste management and, in addition, was an expert in the recent commission on waste-incineration tax. In this programme, he will lead Projects 1 and 10.

Göran Östblom, PhD at the National Institute of Economic Research, has extensive experience from general equilibrium modelling and is the creator of the applied general equilibrium economic model, Environmental Medium term EConomic model (EMEC). In this programme, he will lead Project 2.

Patrik Söderholm, Professor of Economics at Luleå University of Technology, has a strong research focus on analysing and modelling the impacts of policy instruments in the waste and energy sectors. Professor Söderholm currently co-ordinates the SHARP research programme on sustainable households. In this programme, he will lead Project 8.

The TOSUWAMA team involves several other researchers. The list of participants currently includes:

Jan-Olov Sundqvist, *Åsa Stenmarck*, *Lisa Hallberg*, and *Jenny Arnell* at IVL. The first three have a long experience from waste-management research, including environmental and economic assessments of waste-management systems. Ms. Arnell is an experienced co-ordinator of courses and seminars.

Johan Sundberg and *Mattias Olofsson*, both PhDs at Profu i Göteborg AB, have extensive experience from waste management research and systems analysis. Dr Sundberg was research leader for the Waste management group at Chalmers 1993-2005. Both have been involved as experts in many of recent national investigations of policy instruments.

Ola Norrman Eriksson, PhD at the Department of Technology and Built Environment at the University of Gävle, has experience from LCA of waste management.

Raul Carlson and *Sandra Häggström* at the Division of Industrial Environmental Informatics, have an extensive experience from defining requirements for environmental databases.

Karl-Henrik Dreborg, PhD, *Mattias Höjer*, PhD, and *Greger Henriksson* doctoral student at the Division of Environmental Strategies Research at the Royal Institute of Technology have experience from LCAs of waste management, futures studies, and ethnology.

Magnus Sjöström, PhD at the Environmental Economics Research Division at the National Institute of Economic Research, has experience in econometric and general equilibrium modelling.

Anna Dahlqvist, doctoral student in Economics at Luleå University of Technology.

Jenny Sahlin, doctoral student in Energy Systems Technology at Chalmers University of Technology.

The mix of university researchers and more commercial research groups brings complimentary networks to the programme (see Section 5.1). The mix of men and women is also well balanced: 50/50 in project leaders and 56/44 in other team members.

Co-ordination of TOSUWAMA will be an important and complex task. A management committee, with the project leaders, Dr. Ljunggren Söderman, and an EPA representative, will be established. This committee will meet each autumn with the purpose to discuss the co-ordination of the programme and other strategic issues and to give advice to the programme leader. Between the physical meetings, they will be in contact through email and/or phone conferences.

The programme will also include a reference group with representatives from the waste-management sector, consumers, and external researchers. This group will meet each spring to discuss the approaches and results of the programme and to give the researchers inspiration for the continued research. The members of the reference group will also be a valuable source of information for the individual researchers. We will be able to expand the reference group during the course of the programme, but initially it is fairly small:

- The Swedish Association of Waste Management (RVF; has been invited and expressed an interest to participate but will decide on the representative(s) when the application has been approved)
- Johan Jareman, the Swedish Consumer Agency (confirmed)
- Bostadssektorns Avfalls- och RestproduktGrupp (ARG; has been invited and expressed an interest to participate but will decide on the representative later)
- The Swedish Society for Nature Conservation (has been invited and expressed an interest to participate but will make a definite decision later)
- Annika Helker-Lundström, the Swedish Recycling Industries' Association (confirmed)
- Christer Forsgren, Stena Metall (confirmed)
- Professor Anne-Marie Tillman, Chalmers University of Technology (confirmed)
- Professor Thomas H. Christensen, Technical University of Denmark (confirmed)

5. Communication plan

5.1 Conditions for communication

The interdisciplinary nature of this research area calls for a multidisciplinary research team. Such a team will inevitably encounter communication problems. The same words can have different meaning in different disciplines. Researchers in different disciplines can also disagree on how research achieves high quality and on the role of researchers in society. In this programme, we have succeeded in gathering researchers that share a common view on the purpose of the programme. Most of us also have experience from as well as an interest in crossdisciplinary research. This makes it easier to find a common understanding on the terminology, the research issues, and the results.

External communication is important in every scientific project. When the research is directly relevant to the society such communication is particularly important to obtain adequate information from the stakeholders as well as to disseminate the findings.

The TOSUWAMA team includes a mix of university researchers and more commercial research groups with complimentary networks and channels for communication. The academic researchers have a well-established international network of research colleagues. Prof. Söderholm is also a member of the EPA environmental research committee (Miljöforskningsnämnden), and Prof. Finnveden is a member of the EPA waste council (Avfallsrådet). The National Institute of Economic Research has well-established links to the Ministry of Finance, the Ministry of Sustainable Development, the EPA, and the Swedish Energy

Agency. Both IVL and Profu have a commercial interest in ensuring that the results and conclusions of the programme will be made available to relevant decision-makers on national, regional and local levels. These complimentary networks and channels are valuable because they allow for efficient dissemination of the knowledge to the scientific community as well as to policy-makers and other stakeholders. The fact that the TOSUWAMA management committee also includes an EPA representative will further contribute to efficient communication with EPA.

Besides the composition of the research team, our external communication will benefit from the practice established by AFR and AFN to arrange an annual conference where researchers and stakeholders met. We expect that the success of these conferences will make it easy to gather stakeholders to our meetings.

5.2 Messages and aim of communication

A vital purpose with the internal communication in TOSUWAMA is to integrate expertise on technology, economy, environment, psychology, ethnology, and futurology into an established science of waste systems analysis. Another important aim is to produce consistent and comprehensive assessments of interesting policy instruments. A third purpose is to utilise the findings of the different projects in a common synthesis.

We anticipate the most important information flows between projects in the TOSUWAMA programme to be the following (see Figure 1):

- from P1 to P2-P6 and P8: suggestions for policy instruments to assess or discuss,
- from P2-P6 and P8 to P1: results from assessments or discussions of policy instruments, suggestions for modifications of policy instruments,
- from P7 to P2: EMEC model with data on future waste quantities in a base case scenario and data on costs for waste-reduction measures,
- from P2 to P3: information on how policy instruments affect waste flows,
- from P8 to P3: input to assumptions regarding what material is replaced,
- from P3 to P9: environmental data,
- between P5 and P6: exchange of information and co-operation in part of the studies,
- from P10 to P1-P9: framework of external scenarios (not illustrated in Figure 1), and
- from P1-P9 to P10: results, experience, insights and background information for the synthesis.

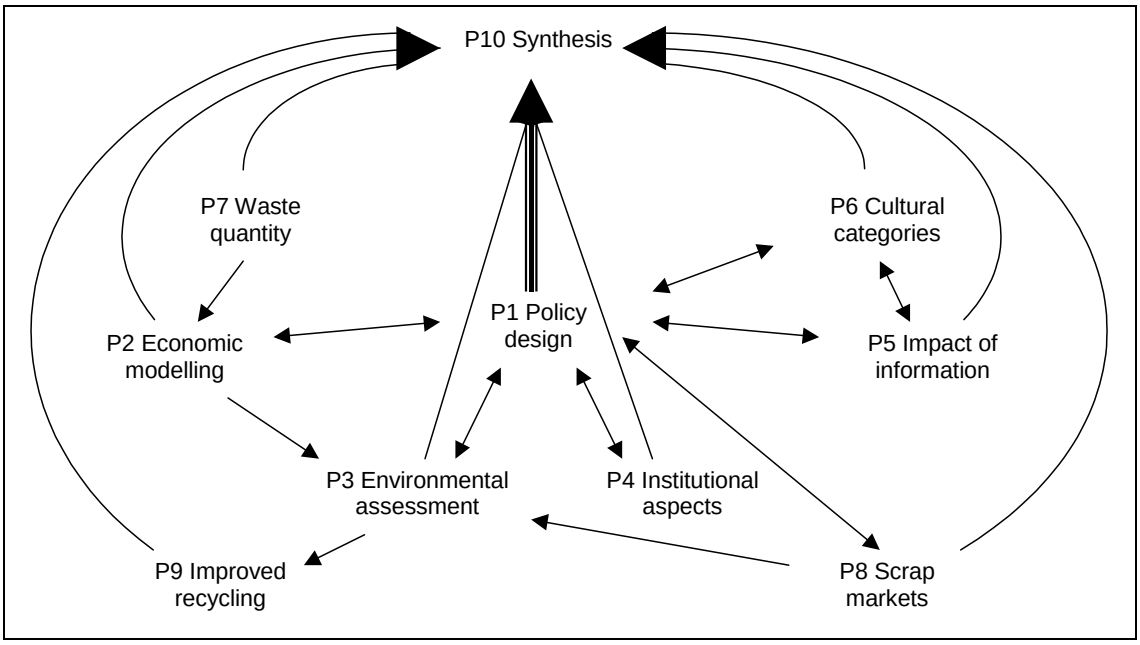

Figure 1: important anticipated information flows between TOSUWAMA projects. The projects are briefly described in Section 3 and more thoroughly in the Project Annexes.

The overall aim of the external communication is to convey understanding on how to make the waste management more sustainable. This will also be the main message of Project 10, the programme synthesis. Other projects will develop and communicate significant pieces of information and insights. These are indicated at an aggregated level by the deliverables in Table 1. For details on the knowledge developed and communicated in the different projects, see the Project Annexes.

5.3 Target groups

The target group for the internal communication is sometimes all researchers in the programme and sometimes researchers in specific projects (see Figure 1).

The primary target group of external communication from Project 9, on environmentally improved recycling, is the companies that recycle material. For the other projects, the primary target for our external communication is EPA. However, the knowledge and insights developed in the programme will be relevant to a very broad group of stakeholders: policymakers at the European, national, regional and local levels, companies that collect, treat and/or generate waste, consumers, environmental NGOs, researchers, and students.

5.4 Communication activities and channels

To integrate the knowledge from new disciplines, each project will include at least one experienced waste-management systems analyst. The tasks of such a person include to supply information on relevant systems aspects to the other researchers in the project, and to help extracting the results and conclusions from the project in a form that can be utilised in the synthesis and in other systems analyses. This will increase the likelihood that all important systems aspects are considered and enhance the integration of the new knowledge in a useful context.

Researchers from all projects will meet each autumn as well as each spring, to develop common external scenarios for the analyses, to exchange information on results, to discuss terminology, etc. The autumn meetings will be internal programme meetings, but the spring meetings will be workshops open to other researchers and to stakeholders. The autumn meetings will be held in

conjunction with the management committee meetings. The management committee will be an important forum for co-ordination of research and communication activities and internal communication and for discussion of other strategic issues. The programme will also have an internet site with separate, internal pages where we post minutes from past meetings, information on upcoming meetings etc. However, for efficient distribution of messages to the research team we will use email.

Project 3, on environmental assessments; will include an activity aiming at harmonising the terminology and data within the programme to reduce the risk for misinterpretation of information flows between the projects. Besides the communication activities that involve the whole programme, there will be an exchange and Cupertino between individual projects (see Figure 1).

Regarding external communication, efficient communication with EPA will be ensured through the TOSUWAMA management committee, and through participation in the EPA waste council and environmental research committee. The annual spring workshops and the reference group will be important channels for presenting our methodological approaches and results to policymakers in general, to companies, and to other researchers. They will also provide important opportunities to get feedback from these target groups.

We will also disseminate our findings to policymakers, companies and representatives from stakeholder groups through an electronic newsletter and through the websites of the programme and its participants. The TOSUWAMA website will include a database on waste flows and the environmental performance of waste-management processes. It will also include documentation from completed workshops and information on upcoming events. And it will include the electronic newsletter and other publications in pdf format.

In addition, we expect that our results will be published in RVF-Nytt and other non-scientific newsletters and journals, which have been interested in our results in the past. The results from Projects 2 and 7 will be published in the KI Working paper series, which is distributed nationally to public authorities, ministries, research institutes and universities. Presenting good examples at the annual seminar of the Swedish Recycling Industries' Association would be an effective method for the dissemination of results from Project 9 to recycling companies.

We will reach other researchers by inviting them to our spring workshops, through our reference group, through our scientific networks such as IEG, through collaboration in other projects, by participating in other conferences, and by publishing scientific reports and papers. The results will also be used for teaching of MSc students at Chalmers University of Technology, the Royal Institute of Technology, University of Gävle and elsewhere. We aim at reaching the public through their representatives in the reference group, through messages targeted at newspapers and other media, and through participation in popular scientific events such as Vetenskapsfestivalen in Gothenburg. If invited, we are also prepared to participate in public debates.

5.5 Resource requirements

Some of the communication activities need to be designed and co-ordinated at the programme level: the TOSUWAMA website, the electronic newsletter, the spring workshop, the autumn researchers meeting, the reference group meetings, and the management committee meeting. These activities will be co-ordinated by Dr. Ljunggren Söderman. She will be assisted by Jenny Arnell and other members of the staff at IVL Kunskap that specialises on arranging courses and seminars. We have assigned 10% of the programme budget (3.0 MSEK) to cover the time spent on these tasks and the associated expenses.

Input to the website, newsletter and meetings will be produced by the project leaders and other researchers in the programme. They will also produce papers, conference contributions etc. to communicate the findings of each project. We expect that 10-20% of the programme budget will be spent on these activities. These activities and the associated costs are integrated in each separate project and not separately presented in the budget.

6. Research plan

The TOSUWAMA projects are briefly presented in Section 3 and more thoroughly in the Project Annexes. As illustrated by Table 1, the first three years will be dedicated mainly to developing new knowledge and to refining the models. The second half of the programme will focus mainly on the assessment of policy instruments and on the synthesis.

Table 1 also presents an overview of the most important deliverables from the programme. In terms of scientific publications we expect the programme to result in at least 20 scientific papers and international conference contributions. Between 5 and 10 of these should be written, if not published, in the first three years. At least one PhD thesis will also be completed in the first half of the programme.

The programme will result in many other publications: research reports, articles in professional journals, etc. (see Section 5.4). We expect to produce one issue of the TOSUWAMA newsletter each year. The programme researchers and the management committee will meet back-to-back each autumn, and the reference group will meet back-to-back with the external workshop.

7. Budget

The costs of TOSUWAMA are presented in Table 2. Of the total programme budget, 10% (3.0 MSEK) is assigned to programme co-ordination. However, 1.05 MSEK is assigned to project leaders participating in the management committee and, hence, added to the separate project budgets. We also assign 10% of the programme budget to co-ordination of communication activities. In addition, communication will be an integrated part of each separate project.

Table 1: time plan of TOSUWAMA. The plan for year 4-6 is preliminary.

	Year	1				2				3				4				5				6			
Proj. No.	Proj. short name / Quarter of year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Policy instruments design												1							2					
2	Economic modelling												3			4									
3	Environmental assessment								5						6			7							
4	Institutional aspects			8												9									
5	Impact of information												10			11									
6	Cultural categories												12			13									
7	Waste quantity								14																
8	Scrap markets									15	16														
9	Improved recycling																			17					
10	Synthesis				18										19										20
	Programme communication		A		B		A		B		A		B		A		B		A		B		A		B
	Co-ordination of programme		C		D		C		D		C		D		C		D		C		D		C		D

Table 1, continued.

Focus of activity	
	Mainly development of background knowledge and tools
	Mainly development and assessment of policy instruments
Deliverables (selected)	
1	First set of policy instruments, to be assessed in Projects 2-7 and subsequently refined
2	Final set of policy instruments, to be used in Project 10 and externally communicated
3	Linked EMEC+NatWaste models, to be refined through assessments of policy instruments
4	Assessment of 1st set of policy instruments, to be reported to Projects 1 and 3
5	Database on waste flows and waste-management available at programme website
6	Database implemented in LCA software
7	Assessment of 1st set of policy instruments, to be reported to Project 1
8	Paper and PhD thesis on incineration tax and institutional aspects
9	Assessment of 1st set of policy instruments, reported to Projects 1 and 3
10	Conclusions on how information affects source separation, reported to Projects 1, 3 and 10, and externally
11	Assessment of 1st set of policy instruments, to be reported to Projects 1 and 3
12	Conclusions on the significance of cultural categories, reported to Projects 1, 3 and 10, and externally
13	Assessment of 1st set of policy instruments, to be reported to Projects 1 and 3
14	Waste data in EMEC in base-case scenario, to be reported to Project 2 and externally, and refined
15	Partial equilibrium models of selected primary and secondary materials
16	Conclusions on the effectiveness of push vs. pull instruments, reported to Projects 1, 3 and 10, and externally
17	Conclusions of the improvement potential of selected recycling processes, reported to Project 10 and externally
18	External scenarios, reported to and elaborated in Projects 2-8
19	Follow-up on the implementation of external scenarios in Projects 2-8
20	Synthesis report, describing strategies for sustainable waste management
Joint meetings	
A	Joint meeting of programme researchers
B	External workshop/conference
C	Management committee meeting, back-to-back with A
D	Reference group meeting, back-to-back with B

Table 2: Budget over projects and participants (kSEK). The budget after year 3 is preliminary.

Participants	Proj. 1 Policy design	Proj. 2 Economic modelling	Proj. 3 Environm. assessment	Proj. 4 Institutional aspects	Proj. 5 Impact of info.	Proj. 6 Cultural cat.	Proj. 7 Waste quantities	Proj. 8 Scrap markets	Proj. 9 Improved recycling	Proj. 10 Synthesis	Progr. commun.	Progr. coord.	Total	First 3 years
IVL Env. Performance		1495	518				600	480	300	240	3000	2100	**8734**	**4758**
Royal Institute of Technology	864		1382			1200			360	1320		300	**5426**	**2511**
Univ. of Gothenburg					2400					120		150	**2670**	**1496**
IVL Env. Technology	648		518			600	600		180	120			**2666**	**1617**
National Inst. Economic Research		1601					600			120		150	**2471**	**1572**
Luleå Univ. of Technology								1920		120		150	**2190**	**1832**
University of Gävle			1037		600				360	120			**2117**	**999**
University of Lund						1200				120		150	**1470**	**800**
Profu	648						600			120			**1368**	**958**
Chalmers Univ. of Technology				720									**720**	**612**
Subtotal:	**2160**	**3096**	**3456**	**720**	**3000**	**3000**	**2400**	**2400**	**1200**	**2400**	**3000**	**3000**	**29832**	**17153**
First 3 years	**1296**	**1796**	**2074**	**612**	**1740**	**1740**	**2160**	**2160**	**0**	**576**				
Management committee		150	150		150	150		150	150	150				
Total:	**2160**	**3246**	**3606**	**720**	**3150**	**3150**	**2400**	**2550**	**1350**	**2550**				
Project leader:	Göran Finnveden	Göran Östblom	Anna Björklund	Tomas Ekvall	Chris von Borgstede	Lynn Åkesson	Tomas Ekvall	Patrik Söderholm	Elin Eriksson	Göran Finnveden				

Most cost figures are dominated by the cost of time spent by researchers in the programme. The exception is the cost for communication, where expenses for arranging workshops and meetings constitute a significant share.

8. Co-funding

Two of the TOSUWAMA projects will be directly co-funded through other sources:

- Project 4, on the waste-incineration tax and institutional aspects, has already been initiated with funding from the Swedish Energy Administration, using approximately kSEK 700 of a total grant of kSEK 2000 for this task. The TOSUWAMA programme will contribute to finalising the study.
- Project 9, on improved environmental performance of recycling processes, will be carried through in co-operation with industry. The companies will contribute with their own time and, possibly, additional research funding. We have also applied for additional funding to this project from Plastkretsen.

The TOSUWAMA programme will benefit from and contribute to several other projects and programmes that we have initiated or applied for, for example:

- SMED: ongoing activity aiming at collecting data on waste flows and emissions for Eurostat (20 000 kSEK /year).
- SHARP: ongoing EPA research programme on sustainable households (kSEK 16 000)
- The universe of waste: ongoing ethnological study of culture and decomposition; funded by The Bank of Sweden Tercentenary Foundation (kSEK 1400).
- Marginal cost of polymer recycling: ongoing cost-benefit analysis; funded by Plastkretsen and EPA (kSEK 576)
- Management of natural resources at households and companies: ongoing project involving behavioural as well as technological environmental research; funded by Forskningsstiftelsen Gästrikeregionens Miljö (kSEK 150); and application for continued project (kSEK 250).
- FORECAST: application for project on life cycle thinking in waste management within the sixth EU framework (kEuro 967, i.e. kSEK 9000).
- Strategies for lean and environmentally benign material cycles. Application to EPA (kSEK 500). This project is particularly relevant to Projects 1 and 10.
- Life cycle assessment of the use of ashes. Application to Värmeforsk (kSEK 500). This project adds an additional waste flow to the environmental assessments in Project 3.
- Various applications to Plastkretsen, totalling kSEK 1700.

We will continue to apply for funds from other sources. As an example, we plan to apply to RVF for projects that reinforce our study on future waste quantities. Up to 2000 kSEK/year can also be made available from the base funding of IVL, provided that a corresponding amount can be obtained from the industry.

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1. Policy instrument formulation

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Sammanfattning

Den övergripande målsättningen med detta projekt är att utveckla nya informativa, ekonomiska, juridiska eller fysiska styrmedel, och kombinationer av styrmedel, som kan leda till ett mer hållbart avfallshanteringssystem. En översikt över existerande och föreslagna styrmedel kommer att genomföras. Efter en första utvärdering kommer några styrmedel (eller kombinationer) att vidareutevcklas och preciseras. Detta behöver göras för att förslagen ska kunna genomgå en fördjupad utvärdering inom ramen för andra projekt inom detta program.

Abstract

The overall aim of the project is to formulate new informative, economic, legislative and/or physical policy instruments and new combinations of such instruments aiming towards a more sustainable solid waste management. A review of existing and proposed policy instruments will be performed. A first screening will be performed and interesting instruments will be further developed in enough detail to allow more detailed evaluation in other projects of this program.

Aim of project

The overall aim of the project is to formulate new informative, economic, legislative and/or physical policy instruments and new combinations of such instruments aiming at reducing the quantity and environmental hazard of waste, and at increasing the environmental effectiveness and overall efficiency.

Contribution to programme objectives

This project is of vital importance for the overall aim of the programme. The policy instruments and combinations thereof should be assessed in other projects. The results from these assessments should be used as basis for new suggestions and for the synthesis towards the end of the programme.

Relevance to society

There is a large number of policy instruments in the waste area (see for example SOU, 2005, for a recent review). It is interesting to note that the currently used policy instruments are largely working from the bottom of the waste hierarchy. For example, there is a tax on landfilling and from 2005, landfilling of organic materials is banned. Also it is most likely that Sweden will introduce a waste incineration tax this year. The proposed tax is put on the fossil parts of the incinerated waste only, in line with the taxation of other fossil fuels.

However, the jigsaw puzzle of policy instruments is not complete. For example, it can be noted that except for materials falling under the extended producer responsibility, and for products with a refund system, there are currently no policy instruments which promote recycling and reuse of materials (SOU, 2005). The new incineration tax will perhaps partly fill this gap, but only for some materials. Also for the top priority, waste prevention, there is a significant lack of instruments. The recent governmental committee on taxation of incineration of solid waste (SOU, 2005) also concludes that their suggestion is probably not enough to reach the goals. Therefore they suggest

that the new tax should soon be evaluated and complementary policy instruments should be considered.

One of the interim targets for the Environmental Quality Objective “A Good Built Environment” decided by the Swedish Parliament is that the total quantity of waste generated should not increase between 1994 and 2010 (interim target no 5) (SEPA, 2005). This target will however be difficult to reach since the amounts of waste increase (SOU, 2005).

The increased amounts of waste and the lack of policy instruments for waste prevention, reuse and recycling suggest that there is a need for new policy instruments in the waste area. The environmental benefits from focusing on the upper parts of the waste hierarchy have also been pointed out in some recent studies. Nilsson et al (2005) evaluated a waste incineration tax proposal and compared the results to more visionary scenarios where the waste management system had been optimised including increased recycling. The results indicated that although a tax would probably be environmentally beneficial, the benefits were small compared to the potential suggesting the need for policy tools that can complement different taxes. Also the environmental benefits from waste prevention scenarios have been demonstrated (Olofsson, 2004).

Several different policy instruments were discussed in the recent committee on taxation of waste. Several of them were considered to be interesting. One of the instruments discussed were recycling certificates (Profu, 2004). This would be a parallel to the electricity certificates used to promote renewable fuel for electricity production. In this system, producers using recycled materials would be given recycling certificates for a specific material. The certificates can be traded. Different types of producers would by the end of the year be requested to have a certain numbers of recycling certificates. This could be a policy instrument working towards the use of recycling materials. This is in contrast to some of the current policy instruments, which works towards providing recycled materials to the market, e.g. the current implementation of extended producer responsibility. However, a number of details about the recycling certificates need to be worked out. There are for example fears that the system would be too bureaucratic and complicated. Another aspect concerns how to handle imported goods.

Another example of policy instruments that have been discussed are taxation of raw materials and/or chemical products (Söderholm, 2004). Such a system could stimulate recycling of materials and reduced use of hazardous substances. One important concern in this area is however how this could affect the competitiveness of Swedish industries and if this could be introduced in only one country or if broader international arrangements are necessary.

The examples above illustrate that there are new policy instruments that could be of interest. However they need further development and evaluation. It is thus of relevance to promote research that can further develop and evaluate some of these suggestions and thus bring the discussion further before a next round of waste policy discussions. As an interim result this project will provide an overview of existing and proposed policy instruments in the waste area. Such an overview will be useful for policy makers in governmental agencies and ministries. The researchers involved in this project will also be a resource that can be used in other contexts.

Waste policy is relevant not only for the waste area but also for other policy areas. For example, product policies and chemical policies are related to waste policies. Waste policy can be used to promote changes relevant for the product and chemical policies as well. This is also illustrated by the potential benefits of optimised waste management where the benefits occur mainly in the reduced impacts from production of raw materials and energy carriers, rather than within the waste management system itself (Nilssson et al, 2005).

Theory and methods

Policy instruments are discussed in several scientific disciplines, such as economics (e.g Sterner, 2002) and sociology (e.g. Lindén, 2005). Policy instruments can be divided into four major groups: information, economic instruments, administrative instruments and physical improvements (Lindén, 2005). For the waste management area all these are used. A lot of the emphasis is however on administrative instruments including different types of bans, control schemes and negative economic instruments, e.g. taxes. Physical improvements can help people in different situations to source separate their waste. This is of importance since research indicates that simplicity is of major importance for the results (Sörbom, 2003). Positive economic instruments, e.g. bonuses have only been used to a limited extent but may be of interest.

The project will be divided into a number of interrelated activities.

Literature review and idea generation

A review of existing and proposed policy instruments will be made. The recent committee on taxation of waste (SOU, 2005) provided an overview of waste related policy instruments and also some international outlooks. These overviews will be updated and complemented. We will use literature studies as well as our international contacts to gather information about different types of policy instruments in different countries. This will include looking at instruments for waste prevention in other European countries (Radermaker, 2005, Salhofer et al, 2005). We will also look into positive economic tools and tools promoting the use of recycled materials such as recycling certificates (see also SOU, 2005). Other examples of tools that we will look into are taxation of raw materials and chemicals. Such taxes could possibly promote recycling of materials and reduction of hazardous substances in the waste.

This phase will also include interviews and workshops with stakeholders to generate new ideas. Here we will use our large contact networks both nationally and internationally. An outcome of this activity will be a list and short descriptions of possible policy instruments.

First screening

The policy instruments identified in the first activity will be discussed and screened through a first evaluation in relation to their possible advantages and disadvantages in relation to economic, environmental and social criteria. This evaluation will be qualitative with the aim of identifying policy instruments that should be further developed. Criteria for this evaluation will be defined as a part of the research. In the evaluation we will use inputs from stakeholders and other members of the programme in order to get a comprehensive evaluation. The results from this evaluation will be published. Another outcome of this activity will be a short list of policy instruments that should be further developed.

Further development

The policy instruments identified during the second activity will be further developed. The aim of this activity is to formulate the instruments in enough detail to be able to further evaluate them in the subsequent projects (Projects 2-7). This step must thus be done in cooperation with the other projects in order to ensure that the required details are considered. Results from the different evaluations will be summarised in a final report from the project.

Staff

The project will be carried through in cooperation between three highly qualified experts on waste management with experience from developing and evaluating policy instruments in this area: Göran Finnveden at the Royal Institute of Technology, Johan Sundberg at Profu i Göteborg AB, and Jan-

Olov Sundqvist at IVL Swedish Environmental Research Institute. Other personnel at these three multi-disciplinary institutes may also be involved in the project.

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2. Economic modelling for assessment of policy instruments

Project manager

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Sammanfattning

Inom detta projekt kommer vi att utveckla och använda metoder för att utvärdera styrmedel inom avfallssektorn. Mer specifikt kommer vi att länka ihop NatWaste och EMEC för att få en konsistent beskrivning av interaktionen mellan avfallshanteringen och resten av ekonomin. Detta angreppssätt gör det möjligt för oss att studera såväl samhällsekonomiska effekter som effekter på avfallshanteringen av de styrmedel som föreslås för olika typer av avfallsbearbetning.

Abstract

In this project, we will develop and apply tools for the assessment of policy instruments on waste management, and in particular we expect to create a soft link between the models, NatWaste and EMEC to generate consistent descriptions of the interaction between the waste management system and the rest of the Swedish economy. This approach enables us to study economic effects as well as effects on waste management of policy instruments suggested for waste treatment.

Aim of project

The purpose of this project is to develop and apply tools for the assessment of how different policy instruments in the field of waste management affect the waste treatment as well as the economy. We expect to create a soft link between a systems engineering model for national waste management (NatWaste), and an applied general equilibrium economic model, Environmental Medium term EConomic model (EMEC), to generate consistent descriptions of the interaction between the waste management system and the national economic system. The combination of EMEC and NatWaste will make it possible to assess how legal and economic policy instruments affect the waste flows. It will also facilitate an economic assessment of such policy instruments. The tools developed in this project will be used, to evaluate policy instruments suggested by Project 1: Policy Instrument Formulation.

Contribution to programme objectives

The joint venture between EMEC and NatWaste will facilitate the evaluation of the effectiveness and societal cost of different policy instruments. This is one of the main goals of the research programme. The introduction of waste management costs in EMEC provides a potential for analysing policy instruments aimed at reducing waste generating production processes. Part of this project will be dedicated to assessing policy instruments designed and suggested by the team of Project 1: Policy Instrument Formulation. Our analysis of how policy instruments affect the waste flows will be an important input to the environmental assessments in Project 3. The experiences and insights from the present project will also contribute to Project 10: Future-oriented synthesis.

Relevance to society

The continuous growth of waste flows during the last decade, in combination with the ambition to create a sustainable society implies a need for further development of policy instruments on waste flow management. Due to the lack of efficient policy measures, the previous national environmental target, stating that the total quantity of waste shall not be greater in 2005 than in 1994 was never

fulfilled (Miljömålsrådet 2006). In order to be able to reach the new promulgated target, efficient policies need to be implemented. Naturally, these policy instruments must be evaluated in magnitude and costs to society.

Theory and methods

The literature on economic modelling of waste management has been growing steadily during the last decade (e.g., White et al. 1995, Thorneloe et al. 1998, Callan & Thomas 2001, Eriksson et al 2003, Samakovlis 2004). Many of these studies are economic assessments of waste-treatment options through the use of cost-benefit analyses or similar methods (Lah 2002, EEA 2006). A few studies also assess the consequences of policy instruments (e.g., Ljunggren Söderman 2000).

Computational general equilibrium (CGE) modelling has been used by applied economists for analysing the economic impact of various policy instruments since the early 1980s. It has also gained terrain in the field of environmental economics, as reviewed by Bergman (2005). Only a few CGE model analyses focus on waste management. For example, Weibelt (2001) studies both short-run and long-run effects of an environmental tax on hazardous waste in the South African mining industry. Fahn el al (2003) investigates effects on pollutive emissions and deposition of solid waste of trade liberalization in the Norwegian economy. A CGE model is also used by Bruvoll & Ibenholt (1997) to generate future waste quantities in the Norwegian economy. No literature exists, to our knowledge, on the assessment of Swedish waste-management policy instruments in a general equilibrium framework.

We will introduce a new approach of assessing policy instruments for waste management by linking a general equilibrium model of the Swedish economy, EMEC (Östblom 1999), and a systems engineering model of the Swedish waste management system: NatWaste (Ljunggren Söderman 2000). The former makes it possible to describe how the economic development affects the generation of waste. With the latter we can describe how the choice between waste treatment technologies, depend on economic as well as technological conditions. The combination of models makes it possible to describe how various policy instruments affect the waste quantities and the decisions on waste management technology.

EMEC is developed and maintained by the National Institute of Economic Research for analysis of the interaction between the economy and the environment. The database of EMEC includes IO-data for 69 business sectors, 85 commodities, 150 consumer goods, seven educational groups of labour, a stock of capital, six groups of households, 33 energy carriers and eight pollutants, which permit a wide range of aggregation possibilities. In the model, data are aggregated to more manageable dimensions, distinguishing 27 producing sectors - 26 business sectors and a public sector. Produced goods and services are exported and used together with imports to create composite commodities for domestic use. Composite commodities are used as inputs by industries, for capital formation and household consumption.

The data used in EMEC originate mainly from the Swedish National and Environmental Accounts, whereas the baseline scenario is given by the Long term survey of the Swedish economy 2003/04 (SOU 2004:19) A set of scenarios can be simulated in EMEC and outputs of interest is normally economic growth, production of various industry sectors and pollutive emissions. EMEC has been used by governmental committees (SOU 2005:10, SOU 2003:60, SOU 2001:2, SOU 2000:45, SOU 2000:23), in the long term surveys (SOU 2004:19, SOU 2000: 7) carried out by the Ministry of Finance and in several research projects (Östblom & Samakovlis 2004, Östblom 2003, Nilsson & Huhtala 2000).

The model will be further developed, in Project 7 Future Waste Quantities, to include also the link between the activity in different economic sectors and the quantity generated of different types of waste in the production and consumption of goods and services. In the present project, we take

EMEC one step further by introducing the possibility of waste prevention, i.e. decoupling in each separate sector of waste generation and economic activity. Naturally, such prevention comes with a cost and as a consequence firms will choose between waste prevention and paying taxes and fees or reducing production. Estimates of the waste prevention cost for different economic sectors will be developed in Project 7.

NatWaste is a systems engineering model for strategic planning of national waste management systems. It describes the Swedish waste management system as ten coupled generalised municipal waste management systems. The ten systems in the model are distinguished from each other through four key factors: small/large size, existence /non-existence of district-heating system, existence/non-existence of waste incineration plant, and existence/non-existence of landfill. Each of the generalised systems represents one, or many, real Swedish municipalities. NatWaste is a one-period linear programming model. This means that the model (1) analyses the waste management system for a static time period (normally one year); (2) describes the system in linear equations; (3) optimises the system for a defined objective function, and (4) can include a number of external constraints, such as process requirements, emission constraints and requirements for recovery.

The optimisation objective in NatWaste is minimisation of the total annualised cost for the national waste management system. The costs represent private sector costs (certain taxes and fees are included when stated in the assumptions). The cost function includes variable costs for waste treatment, for local and regional transportation of waste, for auxiliary energy and materials, annualised investment costs for new technologies and expanded waste treatment capacity, and revenues for recovered items. Capital costs for investments already made are not included. Model run outputs include the economically optimal waste management solution (described in terms of total annualised costs), the quantity of waste and material treated in the various processes and energy turnover; and the resulting emissions. The NatWaste model has been used to, e.g., assess the consequences of a tax and bans on Swedish landfilling (Ljunggren Söderman 2000).

The Swedish waste management is evolving rapidly. To allow for an accurate modelling of the current Swedish waste-management system, the datasets in NatWaste need to be updated. To assess how policy instruments affect the future waste management, datasets representing present waste management and future waste-management scenarios must also be added to the model.

We will establish a soft link between the two models. In soft-linking, as opposed to hard-linking, the information is manually transferred between the models. The model users evaluate the results from the models and decide if and how the inputs of each model should be modified to make the models converge. Soft-linking results in a more transparent analysis and a more efficient learning process, compared to hard-linking (Wene 1996).

Depending on different economic scenarios, EMEC will generate future waste quantities for various subsectors of industry and households. These quantities will be used in NatWaste to generate marginal costs of waste management and finally these costs will be incorporated in EMEC. The waste management costs will be a composite of actual costs (transport and treatment) and pass on costs of waste related taxes and other policy instruments. The waste management costs estimated in NatWaste might affect the estimation of waste quantities in EMEC, which means that the procedure is iterative. The iterative process between EMEC and NatWaste will generate a set of observations on the relation between both production and consumption and the cost of waste management. We will generate additional scenarios based on different policy instruments aiming at waste prevention and/or at affecting the choice of waste treatment technology. This makes it possible to estimate:

- The quantities of different waste types generated by various economic sectors in the policy scenarios assessed,
- the optimal mix of treatment technologies applied to deal with the waste,
- the marginal waste-management costs at a national level,

- how the waste flows, waste prevention, mix of treatment technologies and thus the marginal treatment cost are affected by various policy instruments, and
- the wage management policy costs for the waste management system, for other sectors of the economy as well as for the total economy.

Participants in the project are Göran Östblom, PhD in Economics, who has an extensive experience of policy simulations in EMEC, Maria Ljunggren Söderman, PhD in Environmental Science, who has developed Natwaste, and Magnus Sjöström, PhD in Economics, who specializes in econometric studies of policy instruments.

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3. Environmental assessment of policy instruments

Project manager

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Sammanfattning

Avfallshantering kan ge betydande indirekta miljöeffekter genom påverkan på andra tekniska system, såsom energisystem, produktion av material och jordbruk. Genom att ta hänsyn till effekterna över livscykeln vid planering och utformning av avfallshantering, kan sådan oförutsedd och oönskad indirekt miljöpåverkan undvikas. Projektets övergripande målsättning är att bedöma hur styrmedel för avfall påverkar miljön i ett livscykelperspektiv, i syfte att bidra till utformning av styrmedel för hållbar avfallshantering. Existerande och nya data för avfallsflöden och centrala processer kommer att sammanställas och göras tillgängliga på programmets hemsida. Dessa data implementeras i ett generiskt LCA-verktyg för utvärdering av föreslagna styrmedel. Projektet omfattar även harmonisering av terminologi och data inom programmet, i syfte att underlätta och säkerställa korrekt utbyte av data mellan delprojekt.

Abstract

Waste management may cause significant environmental impact through indirect effects on other technical systems, such as the energy system, materials production, and agriculture. Life cycle thinking in planning and design of waste management is a means to avoid such unwanted and unforeseen indirect environmental impact. The overall aim of the project is to contribute to sustainable waste management by assessing proposed waste policy instruments from a life cycle perspective. Existing and new data for waste flows and processes will be compiled and made available at the programme web site. These data will be implemented in a generic LCA tool for assessment of proposed waste policy instruments. The project also includes harmonisation of terminology and data within the programme, to facilitate and ensure correct exchange of data among projects.

Aim of project

The aim of the project is to contribute to sustainable waste management by assessing the effectiveness of proposed waste policy instruments with regard to life-cycle environmental impacts. Waste and environmental process data of the Swedish waste management system will be compiled in a generally accessible data package, and further implemented in a generic LCA-tool which will be used to assess life cycle environmental impacts of policy instruments as proposed by project 1 “Policy instrument formulation”. Substance flow analysis (SFA) will be used as a complement for more detailed analyses of the risk of increased and/or uncontrolled flows of hazardous substances.

Contributions to programme objectives

Assessing the environmental effectiveness of new policy instruments is crucial to ensure that they contribute to a more sustainable waste management, which is the overall aim of this programme. It has been shown previously (Finnveden & Ekvall 1998, Ekvall 1999**,** Eriksson et al. 2005) that major impacts of waste management are often due to indirect effects on other technical systems, such as the energy system, materials production, and agriculture. Life cycle thinking in planning and design of waste management is a means to avoid such unwanted and unforeseen indirect environmental impact. Hence, this project will play a key role in assessing new policy instruments for sustainable

waste management, as proposed by Project 1 “Policy Instrument Formulation”. Insights from this project will also contribute to the future-oriented synthesis in Project 10.

The project will deliver a data package of waste flows and processes for LCA of Swedish waste management. This is a concrete way of realising the programme objective to document results in a way that facilitates their subsequent use in follow-up studies. It will be a valuable source for other parties working with LCA of waste management, and will be an important part of programme dissemination.

Harmonisation of terminology within the programme, which is included as one task of this project, will enhance communication between projects during the course of the programme, and will facilitate efficient integration of results in the final synthesis project.

Relevance to society

An area of priority in the Swedish national waste plan (Swedish EPA 2005) is to enhance Swedish participation in developing waste policy in the EU. LCA in policymaking as a means to modernise the existing legal framework was brought forward by the Commission in its proposed Thematic Strategy on the prevention and recycling of waste (European Commission 2005). Hence, it is strategically important for Swedish authorities to be at the forefront of this development.

The Swedish environmental objective ”A good built environment” calls for high recovery of resources in waste while minimising impacts on health and the environment. To achieve such goals, the Swedish national waste plan prioritises implementation of existing waste policy instruments, while the call for proposal for this research programme highlights the need for new, innovative policy instruments. If indirect effects in other systems are not taken into account in the decision-making process, there is a risk that individual measures and policy instruments may have the opposite effect. LCA provides a consistent framework for addressing the environmental impacts of such indirect effects, to ensure that policy instruments and measures contribute to reduced overall environmental impact.

Yet another area of priority in the Swedish national waste plan, which pertains to the environmental objective “A non-toxic environment”, is to increase knowledge of hazardous substances in waste. This project makes an important contribution by compiling available data in a life cycle framework, allowing for evaluation of policy measures targeting this specific objective.

Theory and methods

LCA as a tool to assess the environmental impacts of waste management has gained in acceptance since it first appeared in the 1990’s, and is today well established (McDougall 2001; Björklund and Finnveden, 2006). Studies in this field concern for instance municipal waste planning (e.g. Björklund et al. 2000; Weitz et al. 1999; McDougall and Hruska 2000), evaluating regional and national strategies or policies (e.g. Nilsson et al 2005; Ekvall et al. 1998; Tillman et al. 1992), and in comparing individual technical processes (e.g. Assefa et al. 2005; Ménard et al. 2004). A number of models have been developed in this field, several of which are available to the participants of this programme.[1]

[1] LCA waste models available to the participants of this programme are ORWARE (Eriksson et al. 2002), the fms-model (Björklund et al 2003), models by CIT/IVL (e.g., Bäckman et al. 2001), and WAMPS (Sundkvist 2006).

Data package for LCA of Swedish waste management

A data package will be compiled, containing data for LCA modelling of Swedish waste management. The purpose of this research program requires a Swedish national perspective, possibility to take into account key local or regional factors, comprehensive and transparent environmental process data, and compatibility with economic models. As none of the available models possess all these qualities, we plan to draw on existing data from several sources, and complement this when necessary to get a complete and up-to-date data package corresponding to the needs of this programme.

To the extent possible, data on waste flows (e.g. waste sources, quantities, and composition) will rely on SMED,[2] as this is likely to become the most reliable and comprehensive source of Swedish waste statistics. Adjustments or complements may be needed to fit the LCA format.

Environmental process data of the foreground system (collection, transport, and treatment) of Swedish waste management will be collected from the models available within the programme and other sources. New datasets may need to be developed for landfills, biological treatment and recycling, due to significant technological changes and improvement. Data on hazardous substances may also need to be improved.

Procedural information included in the data package will specify how to update existing data, add new data, and how to use the foreground data provided in the data package together with background data from other sources.

A data package that is independent from any specific modelling software will ensure transparency, maximise the usefulness of data in other contexts, and facilitate dissemination. It is also a means to ensure compatible levels of data quality among different sets of process data, and provides a structure for adding new data at a later stage. The data package will be made available through the program web site in Excel-format for ease of accessibility.

Implement LCA model

An LCA model will be implemented in a generic LCA tool, combining the data package on waste flows and foreground processes with that of the background system, such as avoided energy and materials production, to achieve the necessary life cycle perspective. Strengths of this approach as opposed to developing a model uniquely for LCA of waste management, are that a generic LCA tool provides a robust structure for life cycle modelling, regardless of the problem at hand; tool integrated routines for data quality control and sensitivity analysis; advanced features for results handling and presentation; and standard LCA databases and impact assessment methods that are regularly updated.

LCA of policy instruments and new technologies

The LCA model will be applied to assess the environmental impacts in a life cycle perspective of existing and new policy instruments as formulated by Project 1. Not all existing policy instruments, however clever and effective in theory, have yet gained full impact in practice. Thus, it is valuable to clarify their potential of contributing to sustainable waste management. This task requires cooperation with Project 2, which will quantify the steering effect of economic policy instruments. The model may also be applied to perform Environmental technology assessment of new, unproved technology, to estimate its potential and assess whether it is worthwhile to further venture and support by some sorts of policy instrument.

[2] SMED (Swedish Methodology for Environmental Data) is developed and maintained in cooperation by Swedish Meteorological and Hydrological Institute (SMHI), IVL Swedish Environmental Research Institute, and Statistics Sweden (SCB), commissioned by the Swedish Environmental Protection Agency.

A set of framework scenarios will be developed in Project 10, reflecting possible variation in external factors that affect or are affected by waste management. These framework scenarios will be used to analyse the robustness (environmental effectiveness under varying external factors) of policy instruments and new technologies.

SFA of toxic substances in recycling

The risk of increased and/or uncontrolled flows of hazardous substances as a result of materials recycling will be investigated. Considering the level of detail regarding substances and processes required for such analyses, system-wide LCA does not appear to be the most appropriate tool. Therefore substance flow analyses (SFA) (Baccini and Brunner 1991) of prioritised substances in more narrowly defined systems will be performed. SFA results will then be integrated with LCA results to complete the picture of this perceived risk and compare to the alternative of using virgin resources. The ORWARE model (Eriksson et al. 2002), which is based on substance flows and allows calculation of iterated loops, appears to be a useful structure for implementing such SFAs.

Harmonising terminology and data

This project relies on exchange of data on waste flows and processes with other projects of this programme. Harmonisation of terminology and data within the programme will be important for this to work efficiently. A conceptual model of the information flows between projects through the course of the programme will be established, and the name spaces, i.e. the nomenclatures, terminologies and categorisations of concepts and terms, of each project will be identified. Existing terminology will be compiled and evaluated for appropriateness in relation to the needs of individual projects and efficient interaction among projects, so that a common terminology can be agreed upon. Recurrent workshops involving all concerned projects will be important in achieving this task. In conjunction to this, sources of data may also be agreed upon, for maximal harmonisation among projects.

Staff

The project is co-ordinated by Dr. Anna Björklund, with long experience of LCA in various contexts of waste management. The project team also consists of Dr. Ola Eriksson, with expertise in LCA and SFA modelling of municipal waste management; Dr. Maria Ljunggren-Söderman, who has experience of waste modelling at the national level; Jan-Olof Sundqvist, who has long and multi-faceted experience of waste management in general, and systems analysis of waste management in particular; and Raul Carlson, with expertise in data management and terminology development in the context of LCA.

References

See main reference list in programme plan.

4. Institutional aspects and the waste-incineration tax

Project manager

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Sammanfattning

I detta projekt utreder vi hur en skatt på förbränning av avfall med fossilt ursprung påverkar avfallsbehandlingen. Vi utreder också den betydelse organisatoriska aspekter har för dessa effekter. För detta syfte använder vi en modell med marginalkostnadskurvor för alternativ behandling av materialfraktioner som idag går till förbränning i Sverige. En skatt som leder till att förbränning fördyras, medför i modellen att en del av det avfall som går till förbränning istället hanteras med andra metoder.

En skatt som riktas mot förbränning av en enskild materialfraktion får avsedd verkan bara om skattens styrande signal kan vidarebefordras till de konsumenter och organisationer som ansvarar för att sortera ut materialet. Om detta inte är möjligt blir skatten i praktiken likvärdig med en generell skatt på avfallsförbränning. Effekten av de organisatoriska aspekterna kan därför beskrivas i vår modell genom att räkna dels på den föreslagna skatten på förbränning av avfall med fossilt ursprung, och dels på en betydligt lägre, generell skatt på avfallsförbränning. Analysen kompletteras med en diskussion om vilka metoder som finns tillgängliga för att vidarebefordra skattens styrande signal konsumenter och organisationer som kan sortera ut det fossila materialet.

Abstract

In this project, we investigate how a tax on incineration of waste with fossil origin affects the waste treatment. We also investigate how institutional aspects affect the consequences of such a tax. For this purpose, we apply a model that includes marginal cost curves for alternative treatment of waste fractions that are currently incinerated in Sweden. A tax resulting in more expensive waste incineration will, in this model, result in part of these waste fractions being treated with other methods.

A tax on the incineration of a specific waste fraction will have the intended effect only if its signal can be transferred to the invididuals and organisations responsible for separating the material. Otherwise, the tax will be equivalent to a general tax waste incineration. The significance of the insitutional aspects can teherefore be described by applying two different taxes in our model: the suggested tax on incineration of waste with fossil origin, and a much lower, general tax on waste incineration. To this analysis, we will add a discussion on what techniques are available for transferring the signal of the tax to individuals and organisations that can separate the material with fossil origin from the rest of the waste.

Aim of project

The project aims at estimating how the proposed incineration tax on waste with fossil origin (Swedish Government 2005) will affect the use of different waste-treatment technologies in Sweden. We also aim at investigating how the effect of such a tax depends on the ability to transfer the tax cost to the individuals or organisations that generate the waste with fossil origin and that can separate this material from the rest of the material. Finally, we aim at identifying and discussing techniques for transferring the signal of the tax to these invididuals and organisations.

Contribution to programme objectives

Development and assessment of policy instruments is an important part of the programme. To be effective, the policy instruments need to affect the organisations and individuals that can affect the waste management. The waste-incineration tax will affect the waste incinerators, but to result in increased material recycling the effect needs to be transferred also to the organisations and individuals responsible for source separation and collection. In general, a policy instrument that is well devised, logical and effective in theory might still be ineffective when applied in an institutional context. Little attention has been given to how the institutional aspects affect the effects of waste-management policies, at least in Sweden. This project will highlight the significance of these aspects for policy-making in the waste-management sector and, in essence, open up a new research area.

The project will result in an estimate of how the waste-incineration tax will affect Swedish waste management. This will be an important part of the assessment of this specific policy instrument, which has received much attention recently.

Part of this project will be dedicated to assessing other policy instruments designed and suggested by the team of Project 1 Policy Instrument Formulation. The results from the analysis of the waste-incineration tax will probably not be directly applicable in this task, but the experience and insights from the analysis of the waste-incineration tax may prove valuable for this assessment. The experience and insights from this project will also contribute to the future-oriented synthesis in Project 10.

Relevance to society

The assessment of the waste-incineration tax is highly relevant because the tax is debated and not yet implemented. If and when the tax is implemented, such an assessment will still be an important part of the follow-up of the policy instrument.

Identifying and highlighting the significance of the institutional aspects will contribute to reminding policy-makers to account for these aspects when designing policy instruments.

Theory and methods

The consultancy Profu (2005) estimated the consequences of the waste incineration tax as part of the official governmental investigation. To analyse how the tax could affect the Swedish waste management, they produced a marginal-cost curve for alternative treatment options of the waste. According to this model, a tax on incineration of plastic waste will make increased recycling of industrial plastic waste very profitable. Increased recycling of plastic waste from households will remain unprofitable, however.

If the owners of the waste incineration plants do not succeed in identifying and charging the organisations and households that deliver plastic waste, they are likely to raise the general waste treatment fee: the tax will affect the fee for incineration of all kinds of waste. In this case, the Profu model indicates that increased recycling of newsprint and industrial plastic will be profitable. Depending on the level of the tax, increased recycling of paper packagings and glass packagings, and biological treatment of biodegradable waste, might also be profitable.

As acknowledged by Profu (2005), their model is simplified. It includes nine waste fractions and presents a single cost figure (with uncertainty interval) for the alternative treatment of each specific waste fraction. In other words, the model does not account for the variability in cost for the alternative treatment of a specific waste fraction. As a result, the model indicates either that alternative treatment of a waste fraction is altogether unprofitable, or that maximum separation and recovery (15-90% depending on fraction) of this waste fraction is profitable. For example, it

indicates that the waste-incineration tax does not make any increase in the recycling of hard-plastic packaging from households profitable.

Our project will use a methodology that is similar to the Profu approach, but that accounts for the variability in cost for the alternative treatment of a specific waste fraction. With support from the Swedish Energy Administration, we have begun developing a marginal-cost model with the eight largest fractions of the household waste that is currently delivered to waste incineration: food waste, newsprint, paper packaging, soft plastics & diapers, yard waste, other paper waste, non-combustible waste, and hard plastics. For each of the fractions, we develop a simple marginal-cost curve to account for the variability in alternative treatment cost. Cost estimates can be found in the Swedish and international literature (e.g., Bäckman et al. 2001, Bruvoll et al. 2002, Hogg 2002, Olofsson et al. 2005).

In this project, we will complete the model of the eight household waste fractions and apply it to describe the effects of:

- the proposed tax on incineration of waste with fossil origin, and
- a tax that will affect the fee for incineration of all kinds of waste through a much smaller raise in the general waste treatment fee.

The latter corresponds to the case when the owners of the waste incineration plants do not succeed in transferring the signal of the tax on fossil waste to households and organisations that generate and can separate this material from the rest of the waste. The model can later be expanded to include also industrial waste and waste prevention.

In addition to the quantitative analysis, we will identify and discuss techniques that can be applied to transfer the signal of the tax to the relevant individuals and organisations. Such techniques include not only methods for identifying and charging the organisations and households that deliver plastic waste, but also improved physical infrastructure for separating and collecting such waste, and information campaigns designed to encurage households to increase the source separation efforts. In this part of the project, we will benefit from the results and insights from Projects 5 and 6.

The project is coordinated by associate professor Tomas Ekvall at IVL. The project team also includes Jenny Sahlin, PhD candidate at the Department of Energy and Environment, Chalmers University of Technology.

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5. Evaluating design and impact of environmental information

Project manager

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Sammanfattning (max 1500 tecken inkl blanksteg)

Syftet med detta projekt är att förstå hur individer i olika kontexter uppfattar olika slags avfallssorteringsinformation. Projektet avser att fokusera på hur individer källsorterar dels i hushåll, dels på arbetsplatser. Projektet omfattar strategisk utveckling och utformning av miljöinformation för att öka medvetenheten kring hur avfall kan hanteras, och syftar till att öka förståelsen kring hur individer i varierade kontexter uppfattar olika förslag gällande hur mängden avfall kan minskas. Särskild finns behov av undersökningar av tillräcklig omfattning för att göra statistiskt tillförlitliga beräkningar på hushålls- och individnivå för att förstå de mekanismer som avhåller hushåll från att övergå till hållbara avfallshanteringsbeteenden. Forskningsfrågor som vi ställer är: Hur kan hållbara avfallshanteringsbeteenden och normer förstås? Hur ser den avfallshanteringsinformation ut som kan riktas mot och accepteras av konsumenter? Hur bör miljöinformation utformas för att kunna riktas till individer i vitt skilda kontexter?

Abstract (max 1500 tecken inkl blanksteg)

The aim of this project is to understand how individuals in diverse settings perceive waste sorting information. Hence, we will focus on waste sorting originating from individuals within households. The steering methods to change the increasing waste amounts are generally supposed to be of financial, legal or informative character. This project includes the development and design of pro-environmental information in a strategic manner to raise an awareness of how waste can be handled, and heads at understanding households' and citizens' perception of various proposals aimed at increasing the waste sorting. We specifically need investigations large enough to make relevant statistical breakdowns on various individual and household segments, to understand the mechanisms that hold households back from converting to sustainable waste management patterns. Research questions that we raise are: How do we understand sustainable waste sorting patterns and norms? What is acceptable and approval waste management information that can be laid upon consumers? How can new environmental information be designed to target the vast variation among individuals in different surroundings?

Project aim

The aims of the project are to:

1. Identify how individuals, and groups of individuals, vary with regard to current levels of environmental knowledge, environmental attitudes and concern, present environmental behaviour (specifically focus on waste separation and recycling) and their inclination to change their behaviour in an environmentally benign direction.
2. Investigate, in collaboration with Project 6, if and under what conditions individuals' social identities in social settings may endorse recycling behaviour. For instance, do ambitious environmental schemes at an individual's workplace spill over to affect the individual's behaviour in the household?
3. Test how different types of environmental information interact with other factors, such as information sources, and individual variations with regard to environmental knowledge, attitudes, behaviour, and propensity to change.

4. Make recommendations for design of information aimed at specific target groups in order to increase individual consumers' and households' sustainable waste management, in particular their participation in source separation schemes.
5. Assess informative policy instruments designed and suggested by, e.g., Project 1.

Contribution to programme objectives

The research programme aims at increasingly sustainable waste management, which can be assumed to require continuing and possibly increasing source separation. The importance of well-designed environmental information targeting people's behaviour and aiming to reduce human-caused detrimental effects on the environment is beyond dispute. This project will contribute to the understanding of how environmental information can be developed and designed in order to increase people's readiness to take part in source separation schemes. Such knowledge is valuable in itself. The insights resulting from this project will also be useful in the design and assessment of informative policy instruments (Project 1), enrich Project 6 (see above), provide background information to the environmental assessments in Project 3, and contribute to the future-oriented Synthesis (Project 10).

Relevance to society

Environmental information is a policy tool that is commonly used to influence people to act more environmentally benign. If environmental problems are communicated in an efficient manner to households, and take individual variation into account, information would be more persuasive in changing people's behaviour. This project will result in insights on how different kinds of well-designed environmental information could appeal to people with varying knowledge, values and attitudes and, hence, improve their readiness to take part in source separation schemes. Such knowledge is valuable because a widespread acceptance and participating in source separation schemes is vital for the ability of the society to close material loops. One of the main questions in this project is how information, as a steering mechanism, reconciles attitudes and behaviour. Information to households about environmental problems (such as the negative impact on the environment of the growing amount of waste) is often communicated through media or via the government. The senders have different agendas and use various channels, but a common way to reach citizens is through newspaper or TV, or via information campaigns developed by different groups in society (such as national agencies, politicians or NGO's). Messages often suffer from a gap between what they wish to convey and what people concede. Thus, there is an urgent need to provide environmental information that matches the level of knowledge and motivation of target groups (see Stern, 2002). Findings from this project are highly relevant for national and local policymakers when communicating with citizens in order to increase waste sorting behaviour. Furthermore, recommendations offered by this project may also be useful both in a short- and long term perspective for the Swedish government to create acceptance among individuals and households for new policy measures. Managing the waste of everyday products usually involves such small risks that consumers are not motivated to deliberate about what alternative to choose. Hence, a discrepancy between people's environmentally unfriendly behaviour and their possibly pro-environmental attitudes are often not brought to mind in daily life. By reminding people of such discrepancies a behavioural change could take place (Eagly & Kulesa, 1997).

The aim of the present project is to design and evaluate information in order to attract people with different motives, different gender, education, age and so forth, as well as different levels of knowledge, experiences and values. It is essential that information aiming at persuading individuals to change their behaviour in a more environmentally benign direction is designed such that people pay attention to it, that it makes sense and that it is credible. Information should be personally relevant to people.

The hypothesis is that different kinds of well-designed environmental information could appeal to people with varying knowledge, values and attitudes and, hence, improves their pro-environmental performance. If environmental problems are communicated in an efficient manner to households, and take natural occurring individual variation into account, information would be more persuasive in changing people's source separation behaviour.

Theory and methods

Theoretical background

Information as a policy tool to encourage personal voluntary changes in waste managing behaviour may be regarded as a low-cost measure in that it is easy to administer and does not require high self-effort to adopt. However, to be efficient in changing environmental behaviour, information must be adopted to the needs of target groups (Stern, 2002).

To take information processing into account, dual-processing theories such as *elaboration likelihood model* (ELM: Petty, & Cacioppo, 1986) and *heuristic-systematic model* (HSM: Chaiken, 1987; Chen, & Chaiken, 1999) have been developed into a comprehensive framework of persuasion. This approach incorporates assumptions of both active, effortful processing, and more effortless processing of information, and how the different modes affect people's behaviour. Moving from attitudes to actual behaviour, it is essential that people are motivated to process relevant information and highly aware of what it is needed to be done. Furthermore, people must also be able to attend to and understand the information. Thus, the theoretical starting point in this project will be to investigate how information is processed depending on motivation and ability.

According to ELM, two routes to persuasion are distinguished. One is called central route, in which persuasion is mediated by effortful scrutiny of messages and other relevant information. The other mode is called peripheral route, which features the influence of non-content aspects in the messages, such as the message source. The key line in ELM is that people, depending on their motivation and ability to process information, vary in which route they use to process any given information. To the extent that they are highly motivated, and also have the ability, the central route is used. Otherwise, the peripheral route is chosen.

A common assumption is that in order to appeal and motivate people to process information, environmental messages should be framed in an altruistic or pro-environmental manner (e.g., Kaplan, 2000). However, other values may be predominant among public. People may also worry about environmental issues that are not commonly associated with waste management. There is little research that has examined the effectiveness of reframing environmental messages more in line with existing values and concerns (Schultz & Zelezny, 2003). The ELM provides mean to scrutinize this approach thoroughly.

Methodological design

The proposed project will generate quantitative results via a mail survey and laboratory experiments. In addition, qualitative data from Project 6 will be used to get a deeper understanding for the mechanisms that either encourage or inhibit certain waste sorting behaviours in households.

Respondent groups in the mail survey will consist of a representative sample of adults living in Sweden. Respondents will be divided into different clusters with respect to age, income, gender, type of housing, and education.

Survey data will cover the areas of a) prevalence of environmental knowledge, environmental concern, values, and interest in environmental issues, with focus on waste management b) waste recycling related knowledge, c) specific waste management beliefs, attitudes and norms, d) previous exposure to environmental information, e) sensitivity to central and peripheral environmental information, respectively, and finally f) readiness to increase source separation.

The second part of the project seeks to map the conditions under which people are prone to attend to new information. The central assumption is that people process information through a central route when they are motivated and able to absorb that information. In this part of the project, we will explore ways to affect the degree of elaboration in people's information processing, even when the motivation to process environmental information is not strong. More specifically, the experiments will consist of, differently designed information about waste management and separation. Information will vary with regard to which values that is emphasized, e.g. environmental or self-interest, and which consequences that are associated with waste management and separation. In a typical experiment, participants will be randomly assigned to one of several groups, and will receive information either via paper instructions or displayed on a computer screen where the manipulation will consist of variations in the information. To the extent that respondents use the central route, they will have a stronger recall and a more positive attitude toward the message. Our hypothesis is that this will be the case when information matches their values and beliefs about consequences. If our results are in line with our hypotheses, reframing of messages more in line with beliefs and value priorities among the general public should prove effective.

By using experimental procedures and random assignment, we will be able to control for naturally occurring individual differences that might influence the results of a correlational study. In addition, by experimentally manipulating information about waste management we will be able to establish the causal relationship between individual differences such as previous environmentally related knowledge, attitudes, values and self-identification, and ability to elaborate new information, which would otherwise not be possible.

To answer the question regarding if there are any spillover effects from waste sorting behaviour within a workplace to waste sorting behaviour in the household we will depart from workplaces that are in the procedure to be certificated by an ambitious environmental sustainable scheme such as ISO14001. Respondents will be scrutinized in several steps, first, before any program has been introduced, then during the installation of the ISO 14001 and finally when the program has been developed and thoroughly implemented. The methods that will be used are, in collaboration with Project 6, qualitative interviews and observations. Comparison between waste management at work and within a household during these steps could bring answer to the questions: What role does forcing behaviour in a structure play on voluntary sorting behaviour in a household? How can information help people to overcome perceived obstacles?

Throughout the project the necessity of a cross-disciplinary approach will be of utmost importance due to the fact that managing waste operates in several areas and on different levels in our society. Furthermore, adopting a cross-disciplinary approach will be most fruitful to achieve clarity and stringency in both developing questions and the method and interprets the data. We will have a continuing collaboration with Kretsloppskontoret in Gothenburg with the aim of encouraging more effective approaches to obtain answers on those questions that are raised in this program. The project will be coordinate by Ph D Chris von Borgstede, at the Department of Psychology Göteborg University. The project team will also comprises Ph D Ola Eriksson at the Department of Technology and Built Environment, University of Gävle. The collaboration will be relevant through the running project in all phases. Ph D Eriksson will bring hard facts about waste and waste management into the project, take relevant contacts with different stake-holders within the waste sector, and together with Ph D von Borgstede develop questions in the survey and interpret results in order to get a broader understanding. Furthermore, he will serve as a link between this project and Projects 3 and 9.

References

See main reference list in programme plan.

6. Sorting things out: considering cultural categories of waste

Project manager

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Sammanfattning

Projektets syfte är att undersöka hur effektiva källsorteringssystem kan åstadkommas utifrån brukarperspektiv. Med utgångspunkt både i hur människor tänker om källsortering och vad de faktiskt gör, utmanas sorteringssystem som konstruerats utifrån tekniska och professionella aktörers perspektiv. Grundläggande kulturella begrepp och kategorier gällande avfall och sopor kommer att undersökas för att uppnå detta mål. Hur konstrueras sådana kategorier, hur fungerar de, hur lärs de in och blir till självklarheter?

Projektet utgår från den osäkerhet som råder gällande rekommendationer för källsortering och insamling. Det gäller dels a) rekommendationernas giltighet och b) deras begriplighet. Det första temat fokuserar på problematiken att källsortering involverar många aktörer, tar mycket sammanlagd tid i anspråk och på osäkerheten om källsortering är värt dessa ansträngningar. Det andra temat fokuserar på motsägelser mellan lekmän och professionella avseende begrepp och kategorier.

Uppfattningar om vad som är sopor, vad som är värdefullt, användbart eller värdelöst vilar på generella och kulturellt grundade värderingar och vanor i vardagslivet. Effektiva styrmedel ska därför inte kollidera med sådana värderingar och vanor. Finns det en kognitiv klyfta mellan lekmän och experter på källsorteringens område? I så fall vill vi beskriva hur den ser ut och hur den kan överskridas.

Abstract

The aim of the project is to investigate how efficient source-separation systems can be designed from a user perspective. Taking peoples established practices, views and wishes about source-separation as a starting point, systems and concepts created by professional actors in the waste-collection market will be challenged. To do this, basic cultural concepts and categories of waste will be examined. How are these categories constructed, how do they work, and how are they being learnt and taken for granted?

Confusion over recommendations for source-separation and collection concerns a) validity and, b) comprehensibility. The theme on validity focus on the fact that source-separation involves a lot of actors, consumes a high amount of time, and on the uncertainty of how important the efforts to sort out really are. Theme b) on comprehensibility, focus on contradictions between laypersons and professionals concerning perceptions of concepts and categories on source-separation.

It is important to bear in mind that perceptions of waste heavily rely on widespread and culturally grounded values and habits of daily life. To be efficient, policy instruments should not contradict such values and habits. If a cognitive gap between laypeople and experts exists, we want to find out how such a gap can be described and exceeded.

Project aim

The aim of this project is to investigate how efficient source-separation systems can be designed from a user perspective. Starting from what people think, wish, and actually do, source-separation based on technology and professional actors in the waste-collection market will be challenged. To

achieve this aim, basic cultural concepts and categories of waste will be examined. How are these categories constructed, how do they work, and how are they being learnt and taken for granted?

Contribution to programme objectives

The project investigates the perception of source-separation to understand the reasons for taking part or not in actual schemes. We also investigate what is required to make a source separation scheme easy to understand and take part in. In our proposed case studies we will look for best practices as well as worst cases. Our methodology will enable us to describe these practices in detail from the users' perspective. The findings will be used within the programme to formulate general rules of thumb concerning user oriented waste handling. The insights resulting from this project will be useful in the design and assessment of informative policy instruments (Project 1), enrich Project 5, provide background information to the environmental assessments in Project 3, and contribute to the future-oriented Synthesis (Project 10).

Relevance to society

Governmental and municipal ambition to make source-separation easy is not least contradicted by a large amount of concepts and categories of waste-fractions such as environmental station, recycling central, recycling station, recycling rooms. What is what, and what kind of waste material that should end up at what spot, is not always easy to grasp. Further reasons to confusion are that source-separation fractions, categorized as "paper, glass, metal, plastic" etc, do not emanate from the material itself, but from the package. People readily discriminate between different kinds of materials but cannot as easily see the point in keeping the same kind of materials apart on the basis of whether it is a package or not (Göransson 2005). Another kind of confusion stems from different local authorities having different policies on source-separation. Examples of clashes and conflicts could easily be multiplied.

This project takes it part of departure in the confusion over recommendations for source-separation and collection concerning a) their validity and, b) their comprehensibility. Concerning validity we focus on the facts that source-separation involves a lot of actors, consumes a high amount of time, and on the uncertainty of how important the efforts to sort out really are – not least because of divergent expert statements of the benefits of source-separation. On comprehensibility, we focus on contradictions between laypersons and professionals concerning perceptions of concepts and categories on source-separation. If a cognitive gap between laypeople and experts exists, we want to find out how this gap can be described and exceeded.

A cultural analysis will give important contributions to the understanding on how decisions on implementation of policy instruments and source-separation systems can contradict cultural conceptions on waste. Such contradictions can obstruct good intentions, willingness and basically positive attitudes towards source separation. To investigate and discuss how an efficient source-separation system can be designed from the users' point of view is an important goal. However, physical improvements need to be combined with other measures related to knowledge, information and public participation. We will study how people handle information and in what ways they participate in local decisions. From these findings recommendations will be formulated on how gaps between expert knowledge and everyday practices can be smoothed out in the future.

It is important to underline that lack of information and knowledge not only concern lay-people. This also holds for experts. For the latter, lack of knowledge are connected to consumers' actions and values in daily life. Gaps between experts and lay-persons should be exceeded both ways.

An important goal for the project is therefore to create useful knowledge for constructing and modifying source-separation systems and waste collection systems so that they fit with culturally grounded habits and perceptions related to waste. Recommendations concerning such user-oriented

solutions will be given within the programme. It is important to direct these recommendations to relevant stakeholders. As we see it there are stakeholders on different levels ranging from those (e g within furnishing, architecture and real estate) who design and install kitchen and housing facilities to those (authorities and producers) that lay down the conditions (legislation) for the producer responsibility and waste handling. In between the municipalities are important actors, but also innovative enterprise engaged in the design of information, as well as collection stations and tecnical equipment. During our research process, it will become clearer what improvements seems most important from the users' perspective. Then the most relevant stakeholders will be identified and adressed.

Theory and methods

Perceptions of order, value, usefulness etc. heavily relies on general and culturally grounded values and habits of daily life (Douglas 1966, Hawkins & Muecke 2003, Thompson 1979). It is important to underline that the project concerns both how people *think* of concepts and categories and what they really *do*. Attitudes versus behaviour have been studied in the so called field of garbageology (Mayne & Murray 2001, Rathje 2001). The project will benefit from previous studies on source-separation (Berg 1993, Berg 2001, Browner 1999, Dahlén 2005, Ojala & Höijer 2005, Sörbom 2003); from ethnological research on cultural attrition (Åkesson 2006) and from human ecology on sustainability (Hornborg 2001).

Four case-studies will be made. We intend to describe, and assess the importance of, the users' culturally determined concepts of waste. Households will be investigated in the first two cases proposed below. The third case concerns users in their role as professionals at work. In the fourth arena we focus on mediators hired by municipalities or dwelling companies to inform households about waste handling. Aspects of gender (and gender based division of labour), age, ethnicity, education and different interests in the field will be taken into consideration. Questions will be asked if, and in that case why, some waste are regarded as difficult to sort out, why some waste are not sorted out even if one knows what to do, in what way collection is regarded as functional or dysfunctional. Households, actors and workplaces will be selected in their capacity to illustrate the following themes in a qualitative way, and in their capacity to be culturally generalized (Ehn & Löfgren 2001). To question the taken-for-granted in daily life can be done by network analysis (Kopytoff 1986, Latour 1993), by mapping cultural hierarchies and power relations (Bourdieu 1986), or by investigating narratives, and constructions of identity (Fairclough 1992).

We propose waste diaries followed up by face-to-face interviews, focus-group-interviews, and observations as well-tried and suitable qualitative methods (Godskesen 2002, Wibeck 2000). They will be fit for studying in detail how people handle their waste and use the mental categories in relation to this practice.

Case studies

1. *From waste to value*. Products sorted out for recycling, will be followed through the different actors involved. Family-members will give statements of how to sort out, and where to bring the used or rejected things. The actors that follows in the process will be scrutinized until, finally, the waste are recycled into a new context gaining new value. Focus will be on plastic, metal, paper, clothing and food. Particular interest will be devoted to matters of concepts and categories of waste fractions, and how recycling routines could be made easier.

2. *Waste that worries*. To what extent are hazardous leftover domestic consumer products such as oil, paint, solvents, batteries, chemicals, medical drugs, electronic waste and the like, flushed down the toilet, thrown in the dustbin or kept until a tour to the "environmental station"? The same households as mentioned above will serve as informants supplemented with professional actors

taking care of hazardous waste. What would be needed, from a user perspective, to avoid mixing hazardous waste with ordinary household waste?

3. *Waste at work*. We examine how policies for source-separation are maintained and followed on a daily basis, and if what people do at work differ from what they do at home. Based on our knowledge on varying efforts in implementing source-separation, workplaces will be selected from the fields of construction, office and hospital. Are separation between personal and workrelated waste comprehensible, maintained, and considered important?

4. *Waste communicators*. Persons talking to residents and bringing about information on source-separation and matters of waste, gain a lot of knowledge of what people consider to be problematic. At least two municipalities will be studied, Gävle and Landskrona. In the latter, the communicators are recruited among young immigrants with the specific aim to discuss waste matters among immigrant residents in the city. The first concentrates on spreading information on how to deal with household-composts in a right way. The relation between information and practise will be investigated. Does information make a difference?

The research team includes ass. professor Lynn Åkesson (coordinator), ethnologist fil.lic Greger Henriksson, the Royal Institute of Technology and Jan-Olov Sundqvist at IVL. Åkesson and Henriksson will be responsible for the cultural analysis. Sundqvist will contribute to relevant choises of places and persons for fieldwork and interwievs. Sundqvist's international experience of source separation in practise will also gain the project, not least if international comparision turns out to be important in understanding Swedish habits and values. The project team will meet regularly to discuss and adjust project outline during fieldwork, data collection, analysis and report outlines. The project team will also meet regularly with the team of Project 5, to discuss collaboration and findings.

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See main reference list in programme plan.

7. Future waste quantities

Project leader

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Sammanfattning

I detta projekt studerar vi hur mängden avfall kommer att utvecklas i framtiden. Vi studerar också hur mängden genererat avfall kan påverkas med olika styrmedel som syftar till att reducera avfallsmängden. För dessa syften vidareutvecklar vi Konjunkturinstitutets miljöekonomiska modell EMEC så att den även inkluderar generering och prevention av avfall. Den modellen används sedan för att bedöma hur stor mängden avfall blir givet olik antaganden om styrmedel och ekonomisk utveckling. Vi utvecklar också en dynamisk materialflödesmodell som beskriver hur mycket material som är uppbundet i långlivade produkter: byggnader, fordon, maskiner mm. Den modellen ger mer exakta bedömningar av den framtida mängden avfall från långlivade produkter.

Abstract

In this project, we investigate how the quantity of waste develops in the future, and how the trend can be affected by policy measures aiming at waste prevention. For this purpose, we develop the environmental medium-term economic model EMEC to include waste generation and prevention. This model is applied to estimate the total waste flows, given a specified economic development and different sets of policy instruments. We also develop a dymanic model of the material stock. This will give more accurate estimates on the future waste flow from durable products such as buildings, vehicles and machines.

Aim of project

The project aims at investigating how the quantity of waste develops in the future, and how the trend can be affected by policy measures aiming at waste prevention.

Contribution to programme objectives

The programme aims at a more sustainable waste management. Keeping the quantity of waste down is an important step towards sustainability. Waste management affects the environment. Even more important, a reduction in waste flows often results in reduced use of material inputs in production processes, which reduces resource depletion as well as emissions from material production. Analysing the options for waste prevention is therefore an important part of the programme.

Estimates on the future waste quantities also provide an important boundary condition for analyses on how the waste can and should be treated. For this reason, the EMEC model will be linked to a model on the Swedish waste-management system in Project 2 Economic Modelling in order to investigate how policy instruments aiming at this system affects the waste management and the economy.

Part of this project will be dedicated to assessing policy instruments designed and suggested by the team of the Project 1 Policy Instrument Formulation. The experience and insights of this project will also contribute to the future-oriented synthesis in Project 10.

Relevance to society

Reducing the waste quantity is one of the top priorities in the national waste-management plan (EPA 2005). The previous national environmental target 15:5 states that the total quantity of waste (excluding mining waste) shall not be greater in 2005 than in 1994 (Miljömålsrådet 2004). For household waste the target was not achieved. The quantity of household waste in Sweden increased by 27 % from 1994 to 2002 (RVF 2003). This increase is part of a long-term trend: the quantity of Swedish household waste per capita has grown more or less exponentially through the 20th century. It has doubled since the 1950ies. The development of the quantity of industrial waste has been difficult to monitor (Boverket 2003), but the Swedish industrial waste intensity (calculated as kg/GDP) is relatively high by OECD standards. The environmental review from OECD (2004) recommends that measures to decouple growth in municipal waste be introduced. The European Commission recently developed a thematic strategy for this purpose (EC 2005). We expect our results to give input to the choice and implementation of policy instruments that aim at waste minimisation. We also expect our project to provide a scientific basis for the discussion on future environmental targets regarding the waste quantity in Sweden.

The large uncertainty in future waste quantities adds to the problems of waste management planning. This problem is serious because the planning requires large, long-term investments. The currently ongoing and planned investments in waste incineration alone will be in the order of 20 billion SEK. We expect the results and knowledge from our project to reduce the risk of making large investments in “wrong” technologies. Our research will also make it easier to coordinate measures for waste minimisation and the planning of infrastructure for waste management.

The project is scientifically relevant because it initiates Swedish academic research in the area of future waste flows. Contrary to many previous studies on the international level, we combine economic and technological expertise to match the apparently cross-disciplinary nature of the problem. Together with previous Swedish assessments of waste-management options, our study will provide a basis for national waste-management scenarios that include the generation as well as the treatment of future Swedish waste.

Theory and methods

Bruvoll & Ibenholt (1997) and Andersen et al. (1999) describe the future quantities of different waste fractions from different sectors in society as functions of the activity in these sectors, of technological progress, and of policy instruments (see "State of the art" in the Programme Plan). We apply a similar approach.

We add data on waste statistics to EMEC, an existing applied economic general equilibrium model at the National Institute of Economic Research (Östblom 1999; see Project 2). Recent data on industrial waste will be made available through the European directive on waste statistics. The Swedish data were collected for Eurostat by IVL as part of the consortium Svenska MiljöEmissionsData (SMED). We also utilize data on past waste flows from the Swedish Environmental Protection Agency (Naturvårdsverket 2004), and from the database AvfallsAtlas® at the consultancy Profu i Göteborg AB.

We will generate relevant scenarios on the future economy in EMEC, based on different policy measures and external factors. We will analyse the available waste data and adapt them to match the EMEC structure of the economy, and we will assess the potential for economic and legal policy measures and technological development to affect the waste intensity in different sectors.

To assess the effects of policy measures and technological development on the waste intensity in different economic sectors, we will analyse the waste data with a top-down and a bottom-up approach. The top-down approach includes a survey over all waste fractions from all economic

sectors to be able to estimate whether they depend primarily on the economic activity in the sector, on the physical input or output, or on the size of the workforce in the sector. This knowledge will be used to ensure that the waste quantity is coupled to correct production parameter in EMEC.

The bottom-up approach includes a more thorough analysis of selected waste fractions on a local or regional scale to estimate the future quantities of these fractions from these sites or regions, and to estimate the cost for reducing the quantities. The analysis will focus on environmentally important waste fractions and on waste flows that during recent years have shown to differ a lot from the basic assumption that the waste quantity is directly coupled to the economic growth. To the extent possible, we will use the results from the specific analyses to make general estimates on the waste intensity and costs of waste prevention in diffeent parts of the economy.

The model EMEC will be fed with data on current waste intensity coupled to accurate production parameter, as well as data on the future waste intensity and cost of waste prevention. We will study how the quantity of waste is likely to develop until the year 2025 in different economic scenarios, as well as how it can be affected by different economic and legal policy instruments. We will apply the model to assess policy instruments designed in Project 1 Policy Instrument Formulation, but we may also use it to assess suggestions on policy instruments from other sources.

To estimate the future waste quantity that is generated through discarding old durable products, it is useful to know the age structure and material content of the durable products that are currently in use. This information will not be available in EMEC. Instead, we will develop a dynamic stock model (cf. Elshkaki et al. 2005) for durable products such as buildings, vehicles and machines. This model will use data on the age structure, material content and expected service life to calculate how the quantity of different waste materials from durable products is likely to develop over time for the next 20 years.

The project is cross-disciplinary and involves an integrated cooperation between economists and engineers specialising on waste-management systems analysis. The economists are Göran Östblom and Magnus Sjöström at KI. The waste-management systems analysts include Tomas Ekvall, Jan-Olov Sundqvist and Maria Ljunggren-Söderman at IVL, and Johan Sundberg, Mattias Olofsson and Jenny Sahlin at Profu.

This project will benefit from and contribute to a project within the sixth EU framework, which we have recently applied for. The EU project aims at mapping the most significant environmental issues of waste management, in a life cycle perspective, and at projecting the future waste quantities from durable products. It will start from the Eurostat data that we have contributed to collecting, and it will use the methodology of dynamic stock modelling on a European level.

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8. Markets for virgin and secondary materials

Project manager

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Sammanfattning

Under det senaste decenniet har flera policyåtgärder implementerats i syfte att uppmuntra till ökad insamling för återvinning av olika avfallsfraktioner. Många av de material som påverkas av dessa åtgärder (t.ex. returpapper, återvunnet aluminium etc.) säljs och köps redan på väl etablerade marknader, och åtgärdernas effekter och effektivitet kommer delvis att bero på dessa marknaders funktionssätt. Detta projekt har två syften. Det *första* är att utveckla en partiell jämviktsmodell som kan användas för att utvärdera effekterna av och kostnadseffektiviteten för ett antal avfallspolitiska styrmedel i Sverige. Modellen beaktar explicit betydelsen av marknadsförhållanden för styrmedlens effekter, samt betydelsen av internationell handel med de återvunna materialen. Projektets *andra* syfte är att applicera modellen empiriskt för att analysera marknadsbeteende (d.v.s. utbuds- och efterfrågereaktioner) för utvalda material (i första hand returpapper, aluminium och stål), samt analysera effekterna av samt kostnadseffektiviteten för en rad policyåtgärder som syftar till att öka graden av materialåtervinning. Projektet kommer också att jämföra resultaten från utländska studier med de som genereras utifrån det svenska fallet.

Abstract

During the last decade several types of public policies to promote increased collection for recycling of municipal waste have been implemented and even more considered. For many of the secondary materials affected by public policy there exist already established markets (e.g., for wastepaper, recycled aluminium, etc.), and the impacts and the effectiveness of the above policies will depend on the functioning of these markets. The objectives of this project are twofold. The *first* is to develop a partial equilibrium model that can be used to assess the effectiveness of a set of recycling policies in Sweden. The model will explicitly recognize the impact of market behaviour on policy effectiveness taking into account also the impact of trade in raw materials. The *second* purpose is to apply the model empirically to analyze the market behaviour (i.e., supply and demand responses) for selected secondary materials (tentatively paper packaging, newsprint, aluminium, and/or steel), and evaluate the behavioural impact as well as the cost-effectiveness of a number of public policies aimed at encouraging the recycling of raw materials. Comparisons with studies covering other countries and the Swedish cases will also be conducted.

Aim of project

The proposed project has two main objectives. The *first* objective is to develop an economic partial equilibrium model, which explicitly recognizes the existence and the behaviour of markets for material collected for recycling. The model will permit an assessment of the cost consequences and recycling impacts of alternative polices aimed at encouraging further material recycling taking into consideration also the impact of international trade. The *second* objective of the project aims at applying this model in the empirical context of paper and metal recycling in Sweden and Europe with special emphasis on the cases of newsprint, paper packaging, aluminium and/or steel. This is done in two steps, viz.: (a) identify and quantify the impacts of the main determinants of supply and demand in the respective secondary markets; and (b) employ the model and attempt at assessing how effective are public policies aimed at increased recycling (see also below).

Contribution to programme objectives

The proposed project should add value to the entire research program primarily due to its efforts to systematically scrutinize recycling efforts and any policy measures intended to promote such efforts in the case of raw materials for which economic markets determine their allocation. This will facilitate a close integration with the "policy instrument formulation" project (Project 1), and provides direct policy implications in the case of a number of selected materials (see also below). More importantly perhaps, while recognizing explicitly that different recycling policies exist but can have very different cost structures, it develops a framework within which these cost divergences can be assessed.

In addition, the research will contribute to environmental assessments of waste management, including Projects 3 and 9, because it deals with an important methodological allocation problem in environmental life-cycle assessment (LCA) (Ekvall 2000). Specifically, for a product life cycle that involves the inflow and/or outflow of recycled materials the question arises to what extent the environmental burdens of primary material production and final waste disposal should be allocated to the product investigated (as opposed to other products where the material is used). In the case of economically traded materials these indirect effects can be properly assessed by modelling the relevant market behaviour, and as such the analysis helps to make LCA a more effective tool for assessing the environmental impacts of different products and services (Ibid.).

The experience and insights from this project will also contribute to the future-oriented synthesis in Project 10.

Relevance to society

Far-reaching policy measures have been undertaken in many economically advanced countries to promote the recycling of different raw materials. The array of public policies includes, for example, surcharges on the disposal of recyclable materials, tax incentives and subsidies to recycling programs, mandated minimum recycled material content to products, virgin material taxes etc. However, the rationale for and the understanding of the consequences of the measures are less than complete. The starting point of this project is that any attempt to promote recycling ought to take into account that in many cases markets exist for collected scrap materials. For these materials it is probably fair to conclude that the ultimate success or failure of any recycling policy will depend on the behaviour of the relevant market actors (e.g., Anderson and Spiegelman 1977). For instance, if the supply of old newsprint is very price inelastic, subsidies directed towards the recovery of newsprint will have only limited impacts, and the relative cost effectiveness of different policies aimed at reducing waste will also depend on market behaviour (e.g., Palmer et al. 1997). For the chosen materials economic markets do exist. Paper products such as newsprint and paper packaging account for a large share of total municipal waste (over a third in terms of quantity generated), and substitution of recycled metals for virgin materials often imply substantial reductions in energy use. As a consequence, increased recycling of these materials could imply significant positive impacts on the environment. Moreover, while policy instruments are often national, in many cases the relevant markets are international in scope and these cross-border interdependencies must be taken into account as well (e.g., Huhtala and Samakovlis 2002, Van Beukering 2001).

The results will imply several policy implications for the respective materials considered. Most importantly, they will indicate whether there exist differences in the intervention levels necessary to accomplish a given reduction in waste disposal with various policies. As a consequence, they will offer guidance to policy makers in choosing among different policies that incorporate recycling incentives. On a more general level the analyses will also indicate in what way the different waste management policies interact with the markets for secondary materials, and in this way identify the most significant obstacles to increased raw materials recycling.

Theory and methods

Methodologically the investigation: (a) assesses econometrically the market behaviour for a number of secondary materials; and (b) uses this information as input in an economic partial equilibrium model to evaluate the impact as well as the cost effectiveness of various recycling policies.

The *first* part of the research effort specifies and estimates econometric models of selected secondary materials markets and any inter-related markets. The objective is to identify and quantify the impacts of the main determinants of supply and demand in these markets, in particular the own- and cross-price elasticities of supply and demand. The demand models take into account the fact that secondary material demand ultimately is a derived demand for inputs to produce new products (Lundmark and Söderholm 2003). Important geographical differences in terms of virgin material production and secondary material generation exist, and these will plausibly give rise to varying demand and supply structures. To the extent that this is possible the geographical dimension will be taken into account as will the impact of exports and imports on materials use and prices. The results from the econometric analyses can be used to assess: (a) the own-price elasticities of demand for factor inputs, including both secondary and virgin materials; (b) the cross-price elasticities between secondary and virgin materials; (c) the price-responsiveness of secondary and virgin supplies; as well as (d) the impact of other independent variables on demand and supply behaviour. A large share of the data needed to estimate the above models have already been collected, but additional data collection is needed and in some limited cases we will have to resort to previous research in order to obtain the necessary information.

The main purpose of the *second* part of the project is to evaluate the effect and cost-effectiveness (i.e., how much more recycling per dollar expended) of various recycling policies. One of the most accepted conclusions in the field of environmental economics is that the use of economic incentives have a number of advantages over so-called command and control (CAC) regulations (which 'command' a particular behaviour) (Baumol and Oates 1988). First, there is strong evidence (both empirical and theoretical) that the former can obtain set environmental goals at significantly lower costs than a regulatory regime. In addition, economic incentives provide continuing incentives to invest in new environmentally friendly technologies. However, while the choice between CAC regulation and economic incentives often is fairly straightforward, the choice between different price-based policies is not. This part of the project entails a comparison of a number of different price-based policies all intended to make consumers sensitive to the costs of transporting and disposing of waste at landfills and incinerators, will be undertaken.

Since illegal dumping often is the feared consequence of upfront policy approaches (e.g., Fullerton and Kinnaman 1995), such as charging households by the amount of waste generated, we focus on a number of indirect ways to confront consumers with the cost of handling and disposing of the waste generated. These policies include, for instance: (a) recycling subsidies; (b) advance disposal fees, which are charged to materials producers to cover the ultimate disposal or recycling costs of their products (see also Söderholm 2004); (c) deposit/refund programs, which place a fee or deposit on virgin material when it is purchased and then refund it when the used product is returned for recycling; (d) recycled content standards, which require recycled materials to compose a certain fraction of the final product; and (e) the producer responsibility legislation. The analysis of different types of combinations of policy measures will also be possible, such as the UCTS system proposed by Palmer and Walls (1999).

The policy simulation analysis will build upon and extend the framework presented in Palmer et al. (1997). Building primarily on Sigman (1995), this study develops a partial equilibrium model, which consists of three important relationships (equations): a market equilibrium condition for the secondary material that becomes part of the waste stream, a market equilibrium condition for recycled materials (those reclaimed from the solid waste stream and ultimately reprocessed into new

main products), and a mass-balance identity. The model is calibrated using real world data for a base year. In the proposed project the strengths and the weaknesses of the model in the respective empirical contexts will be analyzed and possible extensions or alternative formulations suggested, not the least with respect to the impact of international trade. The revised model will be employed to investigate the material recycling impacts as well as the cost-effectiveness of the above waste reduction policies in Sweden and Europe, and calibrated with appropriate supply and demand elasticity estimates.

Finally, one important limitation of the study is in order. We do not attempt to assess the overall benefits and costs to society of recycling. The motivations for recycling as such are diverse and often blurred (e.g., ethical concerns towards future generations, environmental education etc.), and are therefore hard to evaluate solely within an economic framework (Ackerman 1997). In addition, price signals towards consumers in the environmental field may result in varying behavioural outcomes following the presence of both social and internalized norms (e.g., Thogersen 2003). For this reason it is useful to provide a systematic comparison of the results obtained here with those obtained in the projects on source separation and collection (Projects 5 and 6), which rely on more complex behavioural assumptions. The main analyses of the project will be conducted during the first part of the TOSUWAMA programme.

Staff and project organization

The project will be coordinated by Professor Patrik Söderholm at Luleå University of Technology, who has considerable experience in the environmental and natural economics research field. The project team also comprises Anna Dahlqvist, Ph.D. candidate in economics at Luleå University of Technology, and Tomas Ekvall at IVL. Dahlqvist's expertise lies in partial equilibrium modelling, while Ekvall will be responsible for ensuring relevance of the project results for implementation results in relevant LCA applications. Ekvall will also assist in the technical validation of the economic models as well as in identifying key relationships in each of the markets considered.

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9. Environmentally improved recycling

Project leader

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Sammanfattning

I detta projekt undersöker vi hur återvinningsprocessers miljöprestanda kan förbättras. Vi utvärderar möjliga förbättringsåtgärder i ett livscykelperspektiv. Vi undersöker också vilka hinder som finns för att förbättringsåtgärderna ska kunna genomföras och vad som kan göras för att undanröja eller försvaga dessa hinder.

Abstract

We investigate what significant, environmental improvements can be made in the recycling processes, and assess these improvements in a life-cycle perspective. We also investigate obstacles to these improvements, and possible actions and decisions that might remove these obstacles.

Project aim

The project aims at identifying and assessing options for improving the environmental performance of recycling processes. We also aim at identifying actions and decisions that are required to facilitate these improvements. The purpose is to stimulate environmentally improved recycling, not only in the companies investigated but in the recycling industry as a whole.

Contribution to programme objectives

The programme aims at a more sustainable waste management. Environmentally improved recycling processes directly contribute to this aim since the environmental impact of recycling will be reduced. Perhaps more importantly, it contributes indirectly to a more sustainable waste management since the environmental arguments for recycling will be strengthened. This increases the acceptability of source separation and recycling schemes. It will be easier to continue or initiate policy instruments that aim at closing material loops and reducing the demand for natural resources.

The project involves the collection of environmental data. It will contribute to, and benefit from, the database developed in Project 3 Environmental assessments. The results and insights from this project will also contribute to the future-oriented synthesis in Project 10.

Relevance to society

The environmental impact of landfilling and waste incineration has decreased significantly during the past 25 years thanks to significant research efforts, technological developments, and environmental restrictions. Similar efforts have not been spent on recycling processes. Recycling processes are also often less mature and smaller in scale compared to production of virgin material. This indicates that significant potential for environmental improvement can exist in recycling processes. The potential has been confirmed, for some recycling processes, through life cycle assessments in the past few years (e.g., Ekvall et al. 2001).

The project will be carried through in cooperation with recycling companies, and focus on the actual recycling processes of these companies. If the project is successful, improvements will be implemented in the processes analysed. Dissemination of information about the project will hopefully also stimulate other recycling companies to consider environmental improvements.

Life cycle assessments and similar studies are based on data that reflect current performance (e.g., Eriksson et al. 2001, Andersson et al. 2001, Bäckman et al. 2001). They typically do not take into

account the improvement potential and might therefore under-estimate the long-term environmental benefits of recycling. Environmental improvements in the recycling processes will affect the results of future environmental assessments, making recycling an even more attractive option than it is in current LCAs. When such assessments are used as basis for decision on recycling schemes, the improvements will make it easier to continue or even expand recycling schemes.

Theory and methods

This project is carried through by researchers on waste-management systems analysis in cooperation with technological and economic expertise at recycling companies. For each recycling plant in the study, we map the environmental impacts in a life cycle perspective to identify environmental hot spots. Full-scale LCAs are not called for in this phase, but life cycle thinking based on the experience of the systems analysts is important. The technological expertise at the recycling companies is also vital in this part of the project.

Improvement options are identified by the technological expertise at the companies. External technological expertise, such as energy-efficiency experts, may also be used in this phase.

The environmental gain of the identified improvement options is assessed by the systems analysts through streamlined LCAs. These will be based essentially on input data that are already available to the systems analysts.

For the most interesting improvement options, the systems analysts cooperate with the technological and economic expertise to investigate why they have not already been implemented. Many different kinds of obstacles may exist: technological, economic, legal, institutional, psychological, etc. We also analyse available options for coming to terms with the obstacles in order to identify

- what is required in terms of changes in legislation, organisation, price setting and so on, and
- who is in the position to change these parameters.

The project is initiated during the second half of the TOSUWAMA programme, and we have not yet decided on what recycling processes and what industrial partners will be involved in the project. We have, however, contacted Fiskeby Mill and SWEREC. Fiskeby Mill recycles paper and board, including laminated board from used milk cartons etc. to produce recycled-fibre based board. This would be a good process to start looking for improvements because the environmental arguments for paper and board recycling have several times been put to question (e.g., Leach et al. 1997). Furthermore, previous studies indicated that the potential for environmental improvements is large in this process: the recycling of laminated board requires much energy and the environmental performance can be significantly improved by changing energy carriers and, possibly, through increasing the energy efficiency (Ekvall et al. 2001).

SWEREC recycles polymers. Polymer recycling is a relatively new process, which means that the potential for further improvements may be significant. More industrial companies will be contacted and the decision on industrial partner will be made at the beginning of phase 2 of the TOSUWAMA programme.

Dissemination of results will be an important part in stimulating improvements in processes that are not analysed in the project. Presenting good examples at the annual seminar of the Swedish Recycling Industries' Association would be an effective method for the dissemination.

This application to EPA aims at covering the research efforts of systems analysts in this project. The time of the technological and economic staff at the companies will be funded by the companies. The companies will also fund any external, technological expertise that is enlisted. The time of the systems analysts will be funded, at least in part, through this research programme. We have also applied for additional funding through Plastkretsens Forskningsstiftelse.

The project is coordinated by Elin Eriksson at IVL. The team of systems analysts also includes dr Anna Björklund at the Royal Institute of Technology, dr Ola Eriksson at the University of Gävle, and associate professor Tomas Ekvall, dr Maria Ljunggren-Söderman, Jan-Olof Sundqvist, Lisa Hallberg, and Åsa Stenmarck at IVL.

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10. Future-oriented synthesis

Project manager

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Sammanfattning

Syftet med projekt 10, *Framtidsinriktad syntes*, är att göra en syntes av resultaten från projekten 2-8 och därmed bidra till programmålet *ett mer hållbart avfallshanteringssystem*. Detta uppnås på i huvudsak två sätt. Dels understöds konsistensen i programmet och en tillräckligt bred analys av robusthet och anpassbarhet hos strategier och enskilda policy instrument. Här används *externa scenarier* som hjälpmedel. Dels presenteras programmets resultat på ett övergripande sätt med hjälp av *strategiska scenarier* som belyser effektiviteten hos paket av policyinstrument under olika yttre omständigheter. På så sätt ska resultaten bli användbara i beslutsfattande och strategiutveckling under osäkerhet.

Abstract

The aim of project 10, *Future oriented synthesis*, is to synthesise the achievements of projects 2-8 and to support the over all Programme aim of a more sustainable waste management. This is achieved 1) by promoting consistency in the Programme and a broad enough analysis of robustness and adaptability of strategies and single policy instruments based on *external scenarios*, and 2) by giving a comprehensive account of the results of the Programme, by working out *strategic scenarios*, where the effectiveness of packages of policy instruments in different external developments are highlighted. In this way the results of the Programme will provide useful input to actual decision-making and strategy development in the face of uncertainty.

Aim of project

The Programme aim is to contribute to the development of a more sustainable waste management in society by identifying and assessing policy instruments and other effective strategic decisions. *The aim of the project 10* is to synthesise the achievements of projects 2-8 and to support the over all Programme aim of a more sustainable waste management by

1. promoting consistency in the Programme and a broad enough analysis of robustness and adaptability of strategies and single policy instruments. Instrumental to this is a set of *external scenarios*.
2. giving a comprehensive account of the results of the Programme, by working out *strategic scenarios*, where the effectiveness of packages of policy instruments are highlighted. The strategic scenarios will have different policy orientations as well as different external framing conditions. The scenarios will be assessed in terms of sustainability.

Contribution to the programme goals

The tasks of the project are best described in terms of its contribution to the programme at large:

Task 1 is to develop a set of 3-5 qualitatively different external scenarios (*Framework scenarios)*, to be used in projects 2-8 as a common framework for assessment of policy instruments;

Task 2 consists in combining external developments based on the Framework scenarios of project 1 with packages of policy instruments, assessed in projects 2-7, into coherent *Strategic scenarios*, and to discuss the over all impact on waste management in terms of sustainability. Furthermore, the robustness and adaptability of policy packages will be analysed. Task 2 is the synthesising phase of the programme.

Relevance to society

The project will synthesise results from the Program in terms of policy instrument effectiveness to achieve a sustainable waste management system. By highlighting the effectiveness, robustness and adaptability of various policy packages across a set of scenarios (different developments paths of society), it will provide useful input to actual policy making.

Theory and methods

The project is divided into two *phases*, each carried out in a number of *steps*. Phase 1 is the development of a set of external scenarios and starts during year 1 and goes on fore 12 months. Phase 2 starts after 3 to 3 ½ year and is the synthesising part of the project. It will run till the end of the Programme. The external scenarios are here combined with packages of policy instruments into strategic scenarios. The two phases are described in more detail below.

Since the effects of policy instruments will appear in the future and depend on the general societal context, some assumptions of salient external developments will have to be made for the assessments of policy instruments in projects 2-8. Working with different assumptions in different projects would lead to problems in the synthesising phase. Therefore a common set of explorative external scenarios will be developed and used by projects 2-8. Besides meeting the consistency requirements, this approach will make it possible to highlight how effectiveness of policy instruments will vary with different external developments. The great advantage of this is that it permits an analysis of robustness and adaptability of policy packages.

Phase 1

Step 1 includes scanning of relevant scenarios made by others. Scoping is also part of this step. By this is meant the identification of external factors that are especially influential as regards waste management.

Step 2 is the working out of scenario skeletons of external developments of relevance to waste management (alternatively, the adaptation of scenarios made elsewhere). This is done in a workshop. The scenario skeletons are then elaborated back-office. A further workshop exercise is devoted to the analysis of threats and opportunities related to different scenarios (SWOT analysis).

Step 3 contains a common methodological inquiry into the use of scenarios in projects 2-8. The general and mainly qualitative framework scenarios will probably need to be more focused on a specific area, tool or aspect (different in different projects) in order to be useful in these projects. A focused scenario will, therefore, be quantified in relevant aspects, but in a way that agrees with the general idea of the related framework scenario. The methodology or principles for quantification of scenarios will be worked out within project 10, with participation of the other project groups. The actual quantification will be carried out within each respective project (2-8). A common seminar will be held when projects 2-8 have started to work with the scenarios. The purpose is to compare the interpretations made by the different groups of the framework scenarios when they try to quantify them. The common seminar is part of project 10.

Phase 2

Step 1 includes reviewing of the framework scenarios based on experiences made in projects 2-8. Also, an overview of results of the policy instrument assessments is worked out.

Step 2 is the development of Strategic scenarios in an iterative, partly workshop based process. First, different general strategies towards sustainable waste management are identified. The strategies are formed by a combination of policy instruments based on some principle, such as *low waste society* or *high level of recycling*. The strategies are to be tested in the different external scenarios. This will give a relatively large set of "first round" policy scenarios, which are then assessed in terms of efficiency. Some strategies may be abandoned because they seem not to lead to sustainability. The remaining strategies are elaborated and improved in order to cope with identified shortcomings or flaws. Possibly, some new strategy may be identified at this stage. The strategies are, again, tested in the different external scenarios, and assessed.

Step 3. Here the scenario exercise is analysed and general conclusions are drawn. These will focus on *combinations* of policy instruments, the *robustness* of policy instrument packages and the *adaptability* of strategies. All assessments are based on the goal of sustainability. The terminology developed in other parts of the Programme will be applied. A final report and a comprehensive article for publication in a peer reviewed journal will be worked out. In the report, it may be sufficient to describe just a few policy scenarios in a comprehensive way, while the remaining scenarios are presented in the form of deviations. This would probably make the report more pedagogical.

Methodology

Scenarios is an important methodological tool in the Synthesis Project. In fact, there exist several scenario tools, two of which are used in this project, viz. *external scenarios* and *strategic scenarios* respectively. For a recent overview of scenario methodologies and a typology of scenarios see Börjesson et al. 2006 (in press).

For the development and implementation of *external scenarios*, a scenario methodology in the tradition of RAND (Kahn & Wiener 1967) and Shell/GBN (Wack 1985, van der Heiden 1996) will be used. It is a participative approach that will involve all project groups of the Programme via workshops with structured brainstorming. Similar workshop formats have been developed by Shell/GBN (Schwartz 1992, van der Heiden1996) and Eden 1998.

The methodology for *strategic scenarios* will combine external developments and strategic elements into scenarios that highlight the interplay between external conditions and policies. This is similar to the approach used in the EU Forth Framework study POSSUM (Banister et al. 2000, Dreborg 2004).

The use of scenarios for robustness and adaptability analysis in the face of uncertainty is an important contribution of project 10 to the Programme. This is in line with an established tradition in Policy analysis and Management (Gausmeier et al. 1998, Dreborg 2004, Eriksson 2004) as well as in Foresighting (Wehrmeyer et al. 2002).

Participation

Fms will lead the work and do some of the back-office work. In Phase 1, 2-3 common workshops will be held and in Phase 2, 3-4 workshops will be carried out involving all the research teams of the Programme. Efforts will also be needed from the other groups as regards assessments of the strategies and single policy instruments in the scenarios.

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