Citizens' Choice
and
Public Policy

A System Dynamics Model for Recycling Management
at the Local Level

vorgelegt von

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von
Reisiswil (Bern) und Trub (Bern)

Die Universität St. Gallen, Hochschule für Wirtschafts-, Rechts- und Sozialwissenschaften (HSG) gestattet hiermit die Drucklegung der vorliegenden Dissertation, ohne damit zu den darin ausgesprochenen Anschauungen Stellung zu nehmen.

St. Gallen, den 04.05.2004

Der Rektor:

Prof. Dr. Peter Gomez

Dedicated to

Arno,
Alexandra, and Sebastian

Foreword

René Dubos' maxim, "Think globally, act locally," has become part of the received wisdom of the global environmental movement. Silvia Ulli-Beer's new book provides practical guidance for solid waste managers at the local level who are striving to make this maxim a reality. The problem that Ulli-Beer tackles is creation of an analytic framework that can relate micro-level decisions made by individual households to macro dynamics of the solid waste policy market taken as a whole.

She begins with a behavioral model of local household decision making that invokes social and psychological factors that drive decisions about when to recycle what types of materials. Working within a single analytic frame shaped by a system dynamics model, she links this behavioral decision-making model to an aggregate view of investment, supply, and demand in the recycling market, all wrapped in a local, regional, and national policy-making framework.

While solid waste management in a single Swiss town bounds the problem focus, her approach is much more general. Issues involving the linkage between individual decision making and regional or even global variables are important to the problems of global warming, resource depletion, sustainable development, and fair trade, to name but a few. Most problems facing environmental managers striving toward a sustainable future can be informed by Ulli-Beer's path-breaking work. Hers is a general framework that needs to be developed and applied widely.

We at the University at Albany are proud to have played some small part in the creation of this work. While living at New Fadum Farm, Ulli-Beer spent a year in residence at the System Dynamics Group at the University at Albany building and refining her model, attending the Thursday Brown Bags, and participating in active research discussions with like-minded researchers.

During her year in residence, we all benefited from her lively and high-energy presence. We are pleased to share some small component of pride in this innovative and exciting work.

<div align="center">

George Richardson and David Andersen

July 2004

Albany, New York

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Preface and Acknowledgments

I remember one episode in a talk about the overall developments of the Swiss Nation relating to sustainability. A distinguished consulting firm was asked to evaluate the current state of the Swiss Nation in the light of sustainable development. The talk focused on the presentation of results from that study.

Evidence suggested that the economy is doing very well and that it is still growing, and the quality, and quantity of the natural environment is sustained, but the societal development is getting worse due to growing poverty, inequality and other factors. Then with this sectored assessment, the policy-makers were left alone in the task of drawing policy implications and of developing comprehensive guiding policy strategies taking into account social, ecological and economic aspects . The talk left me behind with several questions: What is going wrong in a nation, in which the economy is flourishing but the society is wilting? What is wrong with the decision support models stemming from the economic theory which proposes that free economy will lead to a social optimum? Where do we stand now in the light of sustainable development? Which are the driving forces that drift the society towards poverty and inequality?

Those questions are still bothering me. They will not be addressed in this work but a related puzzling issue being addressed in this study on a smaller scale.

A similar paradox can be observed in the current throw-away-society. On the one hand we have a well-organized management of solid waste but on the other hand we have growing waste mountains and costs that are signs of inappropriate production methods and behavior. One way to alleviate this development is by fostering recycling efforts. In doing so, it is important to understand the driving forces that will render recycling initiatives successful in the light of sustainable development. What are micro-processes that will determine the success or failure of a recycling initiative or will lead to unintended consequences? What policy-interventions are promising? What are important preconditions for citizens to engage in recycling initiatives? How can the costs be covered? These are essential questions that should be addressed in order to understand the driving forces that will render recycling initiatives successful.

There exists a rich disciplinary fragmented body of knowledge in the scientific literature that would help address some aspects of those questions. But how can this knowledge be synthesized in such a way that it can inform the decision-making process about the multifaceted dynamically complex real-world issues?

In this book a thesis is presented, which endeavors to address observed phenomena of recycling dynamics from an comprehensive system dynamics perspective, drawing on the relevant disciplinary knowledge. In addition, it offers a decision support model for practitioners that will shed light on the dynamics and cumulative effects of a recycling initiative and should help understand the driving forces that control the observed development. Subsequently, the main intervention points that help steer the development in the desired direction can be identified. Hence, the purpose of this study was to try out an

innovative research approach that would provide adequate insights for practitioners, which would help them to deal with dynamically complex issues on the way to sustainable development. The purpose of this book is to spread this promising approach and different way of thinking among new generations of managers of sustainable development.

This work was not accomplished alone. I am deeply indebted to a wonderful adviser-team that contributed significantly to this work in many different ways. I owe many thanks to Professor Ruth Kaufmann-Hayoz from the University of Berne, who backed up the psychological issues and gave me support from the very beginning till the end of the study. It was due to her openness and trust that, I was able to take this innovative direction in exploring environmentally responsible behavior using a System Dynamics approach. I am especially grateful to Professor Markus Schwaninger from the University of St. Gallen for supervising the dissertation and for his guidance. His prompt and powerful feedback and suggestions, as well as his encouragement of my work, always helped me make tremendous progress. I am deeply indebted to him because he opened the door not only to a new body of thought but also to a whole scientific community, in which I found a home for my thoughts. He made it possible that I could work for one year in a highly inspiring research atmosphere, in the Department of Public Administration and Policy at the Rockefeller College SUNY, Albany. At SUNY, under the mentorship of Professor David F. Andersen and Professor George P. Richardson I learnt what it means to share thoughts between colleagues, to speak about and defend a research topic and to wrestle with research issues personally, as well as to trust in the help of friends. I owe more than I can express to David F. Andersen and George P. Richardson. I am touched by their commitment and their faith in my work. Their extremely stimulating insights and their warm-hearted support have inspired ambition in me that I was not aware of before.

Furthermore, I wish I could thank all my friends and colleagues who have provided valuable comments and encouraged me on the way to this book. Indeed, Aldo Zagonel, Mohammad Mojtahedzadeh, Rod MacDonald, Vedat Diker and Susanne Bruppacher deserve to be mentioned specially, since they not only helped to sort out many thoughts but also showed enthusiasm for this work and broadened my thinking in significant ways.

I also wish to thank Nandhini Rangarajan, Birgit Kopainsky and Kristjan Ambroz for cross-reading the manuscript and for their helpful comments. I also owe thanks to the local authorities, managers, consultants and experts participating in this investigation. Their perspective and wisdom has been crucial for the relevance of this work.

I highly appreciate the financial support of the SNF that was funding the research assistantship and the Basic Research Funds (Grundlagenforschungsfonds) of the University of St. Gallen. Without these grants this work never could have been accomplished.

Finally, I would thank all my friends that provided shelter and warmth to our kids, when their mum was preoccupied with this work and left them back for one year. I am heartily grateful to Anita Ulli-Müller and to my parents Margarete Beer-Heipt and Hans-Rudolf Beer. I am thankful that my father could glance at an earlier version of this manuscript.

This work is dedicated to my two children Alexandra, Sebastian and to Arno, my friend and husband. They are the strongholds that have enabled me to fight this challenging and exciting battle. I am not sure if I could ever give back to them what they have given me in terms of love and support during these demanding years.

Silvia Ulli-Beer

Langenthal, January 2004

Contents

Abbreviations

ESA   Environmentally sound action

REB   Responsible environmental behavior

SPPE   Swiss Priority Program Environment

SNF   Swiss National Science Foundation

CC&P and PPI   Citizens' choice and preferences and public policy initiatives

ISM   Integrative Systems Methodology

SD   System Dynamics

GMB   Group Model Building

SD-SWM-model   System Dynamics-solid waste management-model

ep   experienced peoples

iep   inexperienced peoples

wep   willing experienced peoples

wiep   willing inexperienced peoples

nwiep   not willing inexperienced peoples

nwep   not willing experienced peoples

gbc   garbage bag charge

Notation logic

In this work a System Dynamics Solid Waste Management model (SD-SWM-model) is described. In order to keep the terms in the book consistent with the variables names in the simulation model, the exact terminology is used. Those are indicated as follows:

<fraction separated> or *<iep willing to separate>*

A second peculiarity of this work are the identified loops, they are named and marked separately as follows:

"policy resistance" or **"getting motivated"**

1   **Introduction and overview**

"The whole of science is nothing more than the refinement of everyday thinking." (Einstein, cited in Mankiw 1998:18)

It was probably the book "Limits to Growth" (Meadows, Meadows et al. 1972) that chiefly stimulated the discussion about sustainable development all over the world.

In 1987 the notion "sustainable development"[1] became a political issue through the report "Our Common Future" (WCED 1987). This report and the vision of a sustainable development were deeply discussed in 1992 at the United Nations Conference on Environment and Development and at subsequent conferences[2]. Since then Switzerland and about 179 other nations are on their way to find strategies for sustainable development. As a response to this challenge in 1992 the Swiss National Foundation launched a remarkable program to promote research on relevant topics for a sustainable development, the Swiss Priority Program "Environment" (SPPE[3]).

Actors at the local level seem to be key players in issues relating to sustainable development. On the one hand, decision-makers at the local level are important mediators and are often in charge of implementing national policies (Keating 1993). The success of a national policy depends on a farsighted development of local strategies with which to motivate citizens to comply with public policy initiatives, such as recycling programs[4]. On the other hand citizens have an important influence on the success or failure of specific products and developments of whole industries. Their lifestyles determine what kind of technologies, materials, and resources will be used. Furthermore, with their behavior patterns, they contribute directly to the emergence of environmental problems such as high waste production. Therefore, at the local level, citizens are crucial players for global sustainable development. However, many studies about environmentally relevant behavior show that even environmentally concerned consumers face many obstacles when trying to adopt an environmentally sound lifestyle (Gessner and Kaufmann-Hayoz 1995). Local interventions such as solid waste management policies that help overcome those obstacles can therefore be crucial. In this study these issues will be addressed exclusively for recycling initiatives.

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[1] Based on a philosophical analysis of the United Nations' understanding of the two terms sustainable development and sustainability Di Giulio (2004) points out that a *sustainable development* embodies a global, regional and national development of the society that aims both to meet the (basic) needs / preferences of all human beings, now and in the future as well as to enable them a good life (gutes Leben). Hence *Sustainability* characterizes the state a sustainable development is aiming at. Sustainability is therefore seen as the overall goal. This state is reached when both the (basic) needs / preferences of all human beings and the desire for a good life (gutes Leben) is met and when these are possible for the future generation as well.

[2] For an overview of the political debate see Di Giulio (2004).

[3] http://www.snf.ch/SPP_Umwelt/overview.html

[4] For a theory-based discussion of the role of local authorities see Oates, 1990.

In order to identify and analyze important adjustment processes causing desired and undesired outcomes of national and local solid waste management strategies, the present study adopts a feedback perspective (Richardson and Pugh 1981). Figure 1.1 illustrates the overall feedback process that controls and aims at adjusting societal undesired developments in solid waste management. The development is mainly determined by multistage decision processes at different levels of policy making and by market forces including households and firm choices. This figure illustrates that local authorities are important mediators between national/state policies and citizens in order to reach high policy compliance.
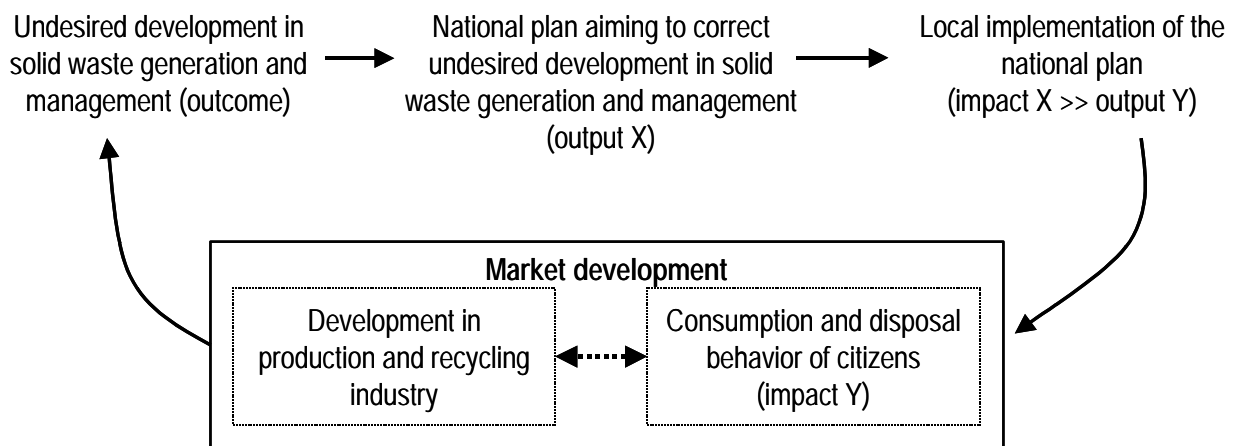
Figure 1.1: Long-term feedback effect of national and local municipal solid waste management policies.

Local authorities are in charge of managing the community, a dynamic complex system that includes different elements interacting with each other. In the realm of solid waste for example there are different actors with various stakes (e.g. citizens producing waste, local waste managers in charge of collecting different qualities of solid waste), different tax- and price-mechanisms, social norms influencing citizens' actions, technologies, products, and public services, as well as infrastructures and so on. The relationships between those elements are often obscure and may lead to undesired developments such as recurrent deficits in solid waste management, or to impurity in separated waste, or to policy resistance of citizens when facing higher garbage bag charges.

For policymakers it may be important to have a heuristic such as the System Dynamics Solid Waste Management-model (SD-SWM-model) developed in this dissertation that helps to understand the processes and factors guiding system behavior and observed phenomena. Such a model should include micro-processes explaining citizens' choices and preferences but also macro processes explaining the dynamics that alter the state of the social system. Subsequently, a useful model can help both to identify effective intervention points and to design / discuss successful policies taking into account environmental (ecological), economic, and social goals.

In sum, this problem-oriented work adopts a System Dynamics perspective. It does so in order to identify essential variables and processes explaining observed developments in solid waste management at the local level relevant to a globally sustainable development.

1.1   The SPPE-Projects: "Overcoming barriers to change" and "Strategies and Instruments"

The conception and the preliminary study for the present study emerged from research within an Integrated Project that was part of the Swiss Priority Program "Environment" (SPPE[5]). In 1992 the Swiss National Science Foundation launched this broad program in order to promote research on relevant topics to a sustainable development. 500 researchers in 200 projects were underway to analyze and understand complex systems in order to find solutions to prevailing environmental and developmental problems[6]. Prof. Dr. R. Kaufmann-Hayoz was the chair of Module 4 *"Environmental Awareness and Activity"* (1992-1995) and the Integrated Project (IP) *"Strategies and Instruments* (working title)"[7] as well as of the sub-project *"Overcoming Barriers to Change* (working title)"[8] (1997-2000). The involvement of the author of this study in the latter two projects was an important experience and shaped the conceptualizations of the preliminary and main studies of the present work. Furthermore, the findings of the three aforementioned research projects (mainly summarized in Kaufmann-Hayoz and Di Giulio (1996a), and Kaufmann-Hayoz and Gutscher (2001)) are important pillars for the proposed thesis.

The objectives of the project *"Overcoming Barriers to Change"* were to open up concepts explaining environmentally relevant actions of citizens and to analyze preconditions for environmentally relevant behavior. Especially, the constraints and hurdles were under focus. Another objective was to design policy measures helping to overcome the barriers to change at the local level. Different methods were used in order to both comprehend the various dimensions of environmentally relevant behavior and to ensure the triangulation of findings[9].

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[5] http://www.snf.ch/SPP_Umwelt/overview.html

[6] For a synthesized overview see (Häberli, Gessler et al. 2002).

[7] Full title: "Strategies and instruments for sustainable development: Bases and evaluation of applications, with special regard to the municipality level with several subprojects" SNF no. 5001-48826, also called Society Sustainability Strategies, see http://www.snf.ch/SPP_Umwelt/SPPE_Management.htm

[8] Full title: "Environmentally responsible behavior in community settings: Theoretical analysis and empirical investigation of overcoming barriers to change" SNF no. 5001-48832.

[9] For a more detailed description of the research objectives, the design and results, see the following literature: Gessner (1998); Gessner and Bruppacher (1999) for a theoretical discussion, Vatter (2001a), and Wittwer (2000) for empirical tests of relevant concepts (survey and "Zukunftswerkstatt"), Bruppacher (2001a) for an empirical actor oriented exploration of different theoretical concepts, Ulli-Beer (1999), Hagen, Hochuli et al. (1999) for an actor oriented qualitative modeling approach.

The main study was funded by the Basic Research Funds (Grundlagenforschungsfonds) of the University of St. Gallen (USG) under the working title "Managing for Sustainability: A Decision Support Model for Solid Waste Management". This study is seen as an innovative implementation of the Integrative Systems Methodology framed by Schwaninger (1997, 2002a). It is especially suitable for investigating complex issues drawing on concepts of System Dynamics and Cybernetics.

1.2   Overview

This book is organized in seven chapters as can be seen in the structural overview presented below (Figure 1.2 A-B).

In Chapter 1, the political stage and the scientific background as well as the main focus of the work is outlined. Chapter 2 illustrates how the study evolved out of two main visions. It specifies the two investigation blocks of the study with its objectives and research questions. Furthermore, the main terms and the field of investigation, environmentally sound action (ESA) and solid waste management are described. It concludes with deliberations on the choice of the method and on the contribution of the study.

1 Introduction and overview

Appeal for a sustainable development   The SPPE-Projects

2 The scope of the study: Dynamic Interaction between Citizens' Choice and Preferences and Public Policy Initiatives

Vision: Gaining a causal understanding of micro and macro behavior   Vision: Offering useful heuristics for decision makers

Research Tasks

Enhance understanding of interactions between human and natural systems	Transformation-knowledge and problem-oriented knowledge transfer

Goal preliminary study: Measures that improve conditions for ESA   Goal main study: SD-SWM-model as policy laboratory

Research Questions

1. What are important factors of ESA?

2. What are important causal structures of ESA?

3. Which interventions are possible to correct harmful trends in solid waste management?

4. Which strategies are most effective? Which combinations of policy-instruments are most promising?

(A)

Chapter 3 describes the different fields of research, from which the investigation draws and emphasizes important links to relevant previous research. Hence, it describes the theoretical background and gives evidence for the assumptions made in the proposed System Dynamics Solid Waste Management model (SD-SWM-model) in Chapter 5. Furthermore, it explains, which research gap the present study tries to explore and to fill in. Also, two main research heuristics were developed or chosen, respectively, that are the first two important milestones on the way toward a SD-model. These are: *"a List of Important Criteria for Public Policy"* and *"a Feedback Perspective on Human Behavior and Public Policy"*.

3 Previous research and theoretical grounding

Psychological theories and concepts

An interdisciplinary perspective

An economic perspective

Identified research gap

A List Of Important Criteria For Public Policy

Economics and SD

Mental models of the system's experts

A Practical Guide For Encompassing Public Policy Design

SD-Models for SWM

Concepts of ESA

Environmental economics

4 Research method and design

SD and GMB

Local government

Strategies and instruments

Results preliminary study

Model conceptualization

5 Understanding the SD-SWM-model

CA theory building

Research paradigm

A feedback perspective

SWM in a feedback perspective

Structure of the model

ISM-Design

Policy implications

Key-loops

Policy experiments

Testing the structure

Strengths and limitations

6 Discussion and reflection on policy, theory and method

Take home messages

Further research

7 Conclusions and further research

(B)

Figure 1.2 A-B: Structural overview of the book

Chapter 4 discusses the basic assumptions of the methods System Dynamics and Group Model Building (SD and GMB) and describes the main characteristics of the applied computer assisted theory building approach (CA theory building) as well as the research design using the Integrative Systems Methodology (ISM).

Chapter 5.1-5.2 lay out the results of the preliminary study, summarized in a further heuristic *"a Practical Guide for Encompassing Public Policy Design"*. Chapter 5.3 portrays the SD-SWM-model conceptualization process. The SD-SWM-model and its basics elements forming the final product, the dynamic theory on recycling dynamics at the local level, are depicted in Chapter 5.4. The two last sections of this result-chapter are dedicated to testing

the model and policy experiments including back-casting, forecasting as well as scenario-experiments. The insights of the various experiments are each summarized in separate sections.

In Chapter 6, the insights are discussed in relation to both the specific solid waste management issues, specified in three sub-questions, and the overall research questions of Chapter 2. Furthermore, the "art of theory development" is discussed and the strengths and limitations of this study are presented.

Chapter 7 summarizes the main findings of the system dynamics view on solid waste management in the form of "take home messages" for both practitioners and researchers. Subsequently, directions for model improvements and its further developments as micro-worlds for policy analysis, as well as a systemic navigation model are given. In addition, ideas for further theory development are outlined. This work concludes with a brief afterthought that brings the reader back to the starting point of the study, addressing the challenge of managing for sustainability.

2 The Scope of the Study: Citizens' Choice and Public Policy

In this chapter the scope of the Study "Dynamic Interaction between Citizen's Choice and Preferences and Public Policy Initiative: A System Dynamics Model of Recycling Dynamics at the Local Level" is described.

The interdisciplinary research focus of the described SPPE projects on the various dimensions of human-environment-relations and their impact on a sustainable development have led to a variety of specific disciplinary insights about single phenomena loosely grouped around environmentally relevant behavior. However, there still remains a gap in the understanding of the interplay of the various factors influencing environmentally relevant behavior. Furthermore, it is very cumbersome for decision-makers to draw useful conclusions from fragmented disciplinary knowledge for their real world problems, as these are often results of complex dynamics in the system.

This work is guided by the vision of, firstly, improving the understanding of the interplay of the different factors influencing ESA integrating findings from different disciplines, and secondly, offering useful heuristics for decision-makers that would help them tackle complex societal problems. These challenges are also recognized as important research tasks by ProClim and CASS (1997). The authors suggest that research should especially aim to improve both system-understanding on interactions between human and natural systems (thesis 9:16) as well as transformation-knowledge in focusing on problem-oriented knowledge transfer (thesis 15:21).

The broader focus of the study is on citizens' behavior and preferences and on public policy. On the one hand it focuses on the behavior of citizens that leads to benefits and costs for the overall society. Policy initiatives usually aim at cooperative behavior that leads to benefits for the community. However, citizens' behavior often generates economically, socially and environmentally problematic (often unintended) consequences that are seen as costs. On the other hand the study focuses on preconditions in the community that influence citizens' behavior. A better understanding of both issues will help design effective policies.

Having this focus, this study is guided by the following three working hypothesis:

- If essential preconditions for environmentally responsible behavior are missing then only a few citizens will develop environmentally sound behavior patterns (Kaufmann-Hayoz and Di Giulio 1996a)

- If local decision-makers aim to improve the essential conditions more citizens will develop environmentally sound behavior patterns.

- If more citizens develop environmentally sound behavior patterns then local decision-makers will face reduced costs.

This general research focus will be applied to a specific problem, related to solid waste separation behavior in a typical Swiss locality. Therefore, a two-step research approach is necessary: Firstly, an overall analysis of environmentally relevant behavior, undertaken in the preliminary study and second, an in-depth analysis of a specific case study, undertaken in the main study. The following chart (Figure 2.1) highlights the two research blocks of this study and gives an overview of the applied research methods. The preliminary study mainly includes a literature review and Group-Model-Building workshops including solid waste management experts. In the main study a computer-assisted theory development method of System Dynamics is applied. It results in a System Dynamics model for Solid Waste Management (SD-SWM-model) that is used for policy analysis.
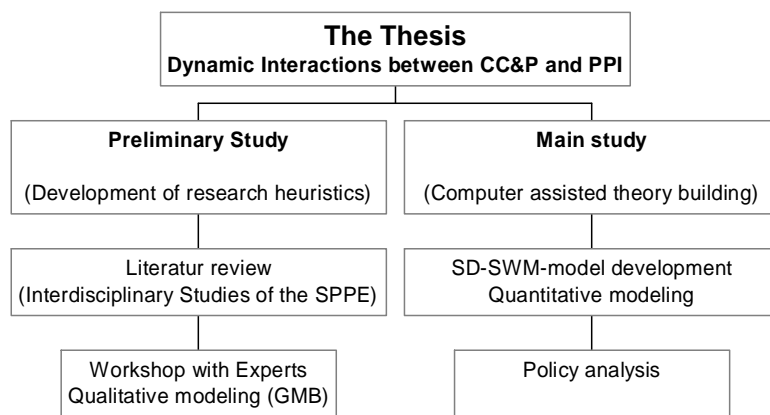
Figure 2.1: Structure and methods of the study (CC&P and PPI: Citizens Choice and Preferences and Public Policy Initiatives).

2.1   The objectives

Based on the research agenda of the SPPE-Project "Overcoming barriers to change" and on the two steps research strategy of this thesis two sets of objectives are formulated.

2.1.1   The goals of the preliminary study

The first investigation block, i.e., the preliminary study was carried out within the scope of the SPPE-Project "Overcoming barriers to change".

The main goal of this study was:

Measures are highlighted that improve the conditions for environmentally sound behavior of citizens.

The following sub goals were set:

- *Crucial variables are pointed out that promote or hinder environmentally sound behavior at the local level.*

- *A simple feedback model of human behavior is developed that illustrates what types of instruments can be used to improve the action conditions at the local level.*

- *A list of important criteria of measures that help facilitate environmentally sound behavior at the local level is created.*

- *A general overview for a quantitative model is sketched.*

Overall the purpose of the preliminary study was to explore and to shape the field of investigation, as well as to develop first concepts that help structure the issue. In order to avoid a disciplinary bias no single disciplinary perspective or single theory approach was chosen. Instead a consistent research heuristic that is adequate for investigating the complex issue was developed.

2.1.2 The goals and research questions of the main study

In the second investigation block, the main study, the sketched concepts of the preliminary study are adopted to the specific case investigating the separation behavior of citizens and local solid waste management strategies. The study strives for an integrated and problem-oriented research approach.

The main goal was set as follows:

A System Dynamics model for solid waste management at the local level is developed in order to design, and test as well as to evaluate strategies and policy-packages.

The quantitative model building process is seen as an iterative theory development process (including falsification and theory refinement steps) that tries to explain important causal relationship leading to unintended consequences in the area of solid waste management.

Therefore, the following sub goals were pursued:

- *New insights are gained about relationships and interactions between important factors influencing the waste separation behavior of citizens.*

- *Coactions of policies and their impact on citizens' separation behavior and the generation of solid waste management costs are tested.*

- *Empirical findings from different theories are used as building blocks and condensed within the model in order to explain the observed real world phenomena in solid waste management from an encompassing perspective.*

- *Complex interactions and processes over time, leading to the observed problems in solid waste management, are visualized.*

- *A computer based learning environment is created that both highlights the interplay of economic, ecological and social factors in solid waste management and helps to analyze the impact of different policy-packages and solid waste management strategies.*

By pursuing these goals the following research questions were answered.

1. *Which factors influence human behavior that lead to harmful environmental consequences in the area of solid waste management?*

2. *Which are the causal structures that produce unintended consequences? What are the interactions between personal attributes (e.g. preferences) and contextual variables (e.g. prices, opportunities to act)?*

3. *Which interventions are suitable to reverse harmful trends in solid waste management?*

4. *Which strategies are most effective? Which combination of policy instruments is most promising?*

2.2   Definition of important terms

2.2.1   Environmentally relevant and responsible behavior

The broader aim of this study is to understand the processes and interactions leading to *environmental problems* of solid waste management. Kaufmann-Hayoz (1996b) defines *environmental problems* as changes in the natural environment of human beings with consequences that are objectionable and are caused by human behavior. Hence, in this work the focus is on a class of human behaviors that have an impact on the natural environment e.g. on the availability of materials or energy from the environment, called *environmentally significant behavior*. Following Stern (2000) this class of behavior includes both the kind of behavior that directly or proximally causes environmental changes (e.g. separation behavior of citizens) and the kind of behavior that shapes the context in which choices are made leading to environmental changes (e.g. local policies influencing the quality of services and their prices or the infrastructure may have indirectly a crucial impact on the environment by determining the preconditions for citizens' separation behavior). Stern distinguishes the *impact-oriented* definition for environmentally relevant behavior from the *intent-oriented* one. The *intent-oriented* definition is seen from the perspective of the actor. The actor may have an environmental intent in his action without having an impact on the natural environment or vice versa; the actor may have no intent to change the natural environment but may cause severe environmental problems. In this case, which seems to be frequently the case, the impact is an unintended consequence (see for example Forrester 1969, Hirsch 1993, Kaufmann-Hayoz 1996b). Stern (2000) points out:

> *"It is necessary to adopt an impact-oriented definition to identify and target behaviors that can make a large difference to the environment (Stern and Gardener 1981). This focus is critical for making*

research useful. It is necessary to adopt an intent-oriented definition that focuses on people's beliefs, motives and so forth in order to understand and change the target behaviors" (408).

In this study we adopt the impact-oriented definition but often literature will be cited that applies an intent-oriented understanding.

Finally *environmentally responsible* or *sound behavior* describes a kind of behavior that aims to solve environmental problems or aims to abate them. This understanding is in line with an intent- and an impact-oriented definition.

2.2.2 Citizens' choice

Since the focus of this study is on environmental policy we will use the term *citizen* rather than *consumer* or *household*. We thus emphasize the relationship between public policy and citizens behavior. The distinguishing criterion is not the character of the good (i.e. public or private good) but the existence of a political agenda that tries to increase (abate) collective benefits (costs).

The term *choice* indicates that citizens will apply a goal oriented decision rule in a specific situation. In those cases it would be more correct to speak of citizens' *action* rather than *behavior*. However, in situations, in which we can observe habits the term *behavior* would be more appropriate.

Furthermore, two different perspectives – the focus on the actors (citizens and local decision-makers) and the focus on the system – lead to two different understandings of the term *behavior*. With a focus on the system the term *behavior* or *behavior pattern* is used to describe changes in a variable of interest over time such as the fraction of separated waste.

2.3 Solid waste management in Switzerland

The general research focus on processes and interactions explaining environmental management problems is specified in the context of solid waste management in a typical Swiss municipality. In the specific case, separation behavior of citizens and policies influencing the context in which choices are made, are analyzed and modeled in order to gain a better understanding of local solid waste management problems. However, such local problems also seem to be crucial for national policies, since they address national and global behavior trends (see Duggan 2002; OECD 2000 in Ludwig, Hellweg et al. 2003).

Solid waste is defined as all the waste that is generated by households including the separately collected recyclable material and similar composed waste from industry and services sector (Art. 3 Abs 1 Technische Verordnung über Abfälle / TVA, see BUWAL 2003:15).

The assessment of the current situation in solid waste management by 'the Swiss Agency for the Environment, Forest and Landscape', can be summarized as follows. The overall achievement of the solid waste policy is a well-organized management of solid waste. But the

whole production and recycling process still involves inordinate consumption of energy and materials. The aim should be to create incentives for waste avoidance and recycling by levying charges for disposal services, and to promote the purchase of long-life products. Sustainable use of raw materials and the search for incentives that promote the necessary changes in behavior are likely to become the key issues for waste management. Waste mountains are a sign of inappropriate production methods and behavior (see SAEFL 2002[10]). However, a comparison between Switzerland and the USA shows that the solid waste management system in Switzerland is relatively advanced (see Table 2.1).

	Switzerland[11]	USA[12]
Amount of solid waste	1.2 kg/person/day	2 kg/person/day
	2.65 pounds/person/day	4.5 pounds/person/day
Recycled	43%	30.1%
Incinerated	57%	14.6%
Land filled	0% (but 0.64Mio t. combusting ash)	55.3%

Table 2.1: Solid waste management in Switzerland and USA (2000).

In Switzerland the Environmental Protection Law[13] (USG) ascribes the responsibility of solid waste disposal to the states (Kantonen). However, they mostly delegate the responsibility for solid waste management to the municipal authorities. The Environmental Protection Law requires that solid waste management services be paid according to the polluter-pays-principle. Therefore, many municipalities levy charges per collected garbage bag (garbage bag charges). That means that the households are required to pay a charge per bag for burnable solid waste. Most other collecting-services for recyclable products (paper, cardboard, glass, ferrous metal - like tins, hazardous waste - like oil, batteries, pet[14]-plastic, aluminum, batteries, food scraps) are free of charge; more precisely it is intended that the costs be covered by basic taxes or by some prepaid taxes. However, the households have to pay an extra price for the disposal of some recyclable material, (e.g. for metal, electrical and electronic equipment and appliances) [15].

As a consequence of the introduction of the garbage-bag-charge-policy, the fraction of burnable waste decreased and the fraction of recyclable material increased. The costs for

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[10]   http://www.umwelt-schweiz.ch/buwal/eng/medien/umweltbericht/druck/index.html (Swiss Agency for the Environment, Forest and Landscape)

[11]   http://www.umwelt-schweiz.ch/buwal/eng/medien/umweltbericht/druck/index.html (Swiss Agency for the Environment, Forest and Landscape)

[12] www.epa.gov./epaoswer/non-hw/muncpl/facts.htm (US Environmental Protection Agency)

[13] Environment Protection Law amended 1997 by the Swiss national government

[14] polyethylenterephtalat

[15] For a historical description of the policy development of the Swiss national solid waste management see for example Ulli-Beer (2000b).

collecting the different streams of recyclable material increased as well. Thus, the municipal budget for solid waste management is growing. There is also a need for monitoring the disposal behavior of citizens, which adds to the costs. Due to higher operative costs and bad recycling-market conditions the relative profit from delivering the separated material to recycling instead to incineration plants is decreasing. The households resist paying higher prices for solid waste management services. Disposal services are not perceived as a cost-effective public service and citizens still expect to get those services for free[16]. This is a critical problem (see Joos, Carabias et al. 2002). However, recent empirical studies give evidence that only a minority of 11% would agree with this statement (BUWAL 2003:34).

In order to disburden the municipality from the high costs for solid waste management and to further promote recycling, the national government discusses the initiation of prepaid disposal charges on more recyclable products. "Advance disposal[17] charges make it possible to apply the polluter-pays principle in financing the comprehensive network of take-back[18] points that is required for a high recovery rate, as well as transport and, finally, environmentally sound processing" (SAEFL 2000:115).

This statement describes the intended effect of the prepaid disposal policy. But there will probably be some unintended effects, as the prepaid disposal charges give different signals to the households and to the recycling sector. It may happen that the awareness of the prepaid price for disposal will decline, and people may put more recyclable material into the burnable garbage. A further side effect could be that the infrastructure for collecting the material could deteriorate. Since there are few incentives for retailers, they are not interested in promoting good collecting services.

A short glance at recycling programs in some localities in New York State shows that they face similar problems. Duggan (2002) recently reported the current situation in the Times Union. Since there is not yet a strong market for recyclable materials, the cities have to pay someone to take the separated material for most collecting categories. Furthermore, the operating expense for picking it up separately generates higher costs than if it would be dealt with as normal "trash". Hence, "recycling" can become economically questionable for the localities. The following two voices of local solid waste management experts point out two major problems they have to deal with. B. Chamberlain, Troy's solid waste management coordinator observes, "If the secondary markets don't improve, the prices to recycle certain material will go up, and once it passes what it costs to landfill it, it won't be economically beneficial" (cited in Duggan 2002). A further important aspect of recycling programs deals with the quality of the separated recyclable material. In the case of New York City they created a useless mix of materials since they collected and compacted glass and plastic together, for which there is no demand. J. Enck, a policy advisor stated: "State law does not prescribe how you are supposed to do the collection. You can sabotage a recycling program if you wanted to" (cited in Duggan 2002).

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[16] http://www.umwelt-schweiz.ch/buwal/de/medien/umwelt/2002_3/index.html (p35).

[17] Advance disposal charges are prepaid disposal charges: the disposal price will be included in the product-price.

[18] Take-back points are collecting points for recovered recycling material.

Three recently conducted national studies describe the state of solid waste management in Switzerland and provide some further reference data for the modeling project. The study analyzing the waste composition (BUWAL 2003) shows that the tax system was the variable that most influenced the waste composition. However, in communities with no garbage bag charges the fraction of separated material increased respectably but less than in communities levying garbage bag charges. Furthermore, broad variation in the fraction separated between communities could be observed, which was explained by the different intensity of collecting services and the demand for those services. On average 45% percent of the solid waste was separated in the year 2000 but findings indicate that there would be a potential for a further increase of 13% up to 58%. However, in order to reach this upper limit more time would be needed in order to convince people. Furthermore, still 5% impurity, that is not recyclable waste, was detected in the separated material. The prices for burning in incineration plants vary between 150 – 300 CHF per tone of solid waste (BUWAL 2002). Interesting differences in the maximal acceptable price per garbage bag were identified between municipalities with and without garbage bag charges: A threshold value of 1.50 CHF per 35 liter bag was reported by 50% of citizens in municipalities without bag charges whereas only 11% citizens in municipalities with garbage bag charge mentioned this relatively low threshold (BUWAL 2003).

These developments in the real world set the stage for the proposed research. Hence, a SD-SWM-model was built

- that explains the observed real world issues of local solid waste management in a Swiss locality

- that gives generic insights into environmentally relevant behavior and

- that subsequently, helps to answer the policy related research questions.

2.4   Deliberations on method choice

"If the only tool you have is a hammer, you tend to treat everything as if it were a nail."
Abraham H. Maslow (1969)

A system (dynamics) perspective for this problem-oriented study was chosen for several reasons. Firstly, the issue of environmentally relevant behavior and the specific real-world problem of solid waste management involve aspects of different levels of behavior, including the micro-level, issues of individuals in their daily life settings (Lebenswelt), and the meso-level, issues on a community level, as well as macro-level concerns of the society. A system analytical approach allows investigating relevant aspects of the different levels.

Secondly, the author tries both to synthesize interdisciplinary findings on the issue and to avoid a disciplinary bias. A disciplinary focus (such as an economic approach) that theoretically predetermines the conceptualization of the problem and the tool for

investigation, may subsequently lead to a disciplinary bias when emphasizing crucial factors explaining the observed problem.

Thirdly, the author assumes that feedback processes may be highly relevant in order to understand the observed phenomenon. A System Dynamics approach with its loop- concept is therefore seen as well suited for the characteristics of the problem. Furthermore, this approach allows encompassing the problem from different perspectives and to include time aspects, internal dynamics and non-linearities. Therefore, it allows accounting for the complexity of the issue.

Finally, the vision to develop a scientifically founded useful heuristic for decision-makers that helps them to tackle their problems was guiding the development of a decision support tool, the System Dynamics Solid Waste Management model (SD-SWM-model).

2.5   Contribution of the study

The present study illustrates a system-theoretically founded approach for an integrated and problem-oriented theory development process trying to explain dynamic interaction between public policies and environmentally relevant behavior, as well as public management problems. More specifically the quantitative model development process helps to analyze and to describe interactive relationships and processes between personal and contextual factors influencing environmentally relevant behavior of citizens. Hence, generic insights about the specific class of environmentally significant behavior can be derived. Furthermore, it helps to understand and avoid policy resistance by focusing on policy compliance conditions.

The understanding of those interactions and processes are important for the design of effective policies not only in the area of solid waste management. Since the specific case addresses a typical phenomenon that is relevant to local solid waste management strategies all over the world, the model structure can be generalized for many cases. Given the "throw away society" we are living in, this study addresses an important research question that helps to recover non-renewable resources as well as to lessen environmental pollution, an issue that might also be crucial for the coming generation.

The study not only generates knowledge about system structure and transformation processes related to environmentally relevant behavior of citizens in the area of solid waste management but also develops a computer based learning environment and communication tool for the decision-maker. The model may enhance discussions about solid waste management strategies between the different actors and may help them to find effective policies in order to increase the quality and quantity of the separated waste. Following the theorem from cybernetics "the result of a management process cannot be better than the model on which it is based, except by chance", after Conant/Ashby (Conant and Ashby 1981), in (Schwaninger 2003a), it is seen as crucial to have an adequate model that helps to explain the observed phenomena.

3   Previous research and theoretical grounding

In chapter three the reader will find a description of the different fields from which the present research will draw. It gives an explanation for why a multidisciplinary perspective was chosen. Furthermore, it explains, which research gap this study tries to explore and to fill in. Hence, the literature review helps to position the work and to ground the model building approach on theoretical data.

The work will be situated in the relevant theoretical context by showing important links to related literature and relevant findings of the SPPE research projects. The SPPE projects serve as an important sample of case studies offering broad conceptual data that could be relevant to the model building process[19]. A further goal of this chapter is to establish a theoretically and empirically based foundation of the main assumptions made in the model. The short overview of relevant disciplinary theories mainly illustrates analogies and convergences of the novel dynamic theory compared with traditional static theories. This helps to evaluate the plausibility of structural hypotheses in the model. Furthermore, the most relevant terms and concepts used in this work or incorporated in the model (such as personal and contextual factors, willingness to pay, decision-concepts, routine and planned behavior, social norms, habits, compliance) will be affiliated and described. They are seen as building blocks of the decision theory used to simulate the decision process in the model. In addition, basic concepts on environmental policies are highlighted in order to present relevant transformation knowledge. Due to the multidisciplinary approach the reader will not find an explicit criticism of existing theories; this would be beyond the scope and objectives of this work.

The present work aims to develop a material theory[20] rather than to falsify and refine existing concepts suggested from other authors.

3.1   Fields of research

According to Vlek (2000) a multidisciplinary collaboration is seen as inevitable in order to understand the nature of environmental problems. Stern (2000) points out that different variables together explain environmentally relevant behavior, some are well understood by psychologists others by economists, sociologists or political scientists. Therefore, an interdisciplinary research approach is required for a better understanding of the interactions. By implementing such an approach, a multidisciplinary basis for policy making could be

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[19] This process of theory development is partly in line with the grounded theory approach (Glaser and Strauss 1967). It advocates a theory development process that is based on data (an inductive theory development process) and not on a logical deduction. Hence, the hypotheses are developed in the process of gathering, coding and analyzing the data – resulting in a theory that is strongly grounded in the specific data. Thus a dynamic theory is suggested that is grounded in both theoretical and empirical data (see Chapter 4 "Research Method and Design").

[20] Glaser and Strauss (1967) distinguish material from formal theories. A material theory is developed for a specific topic (such as solid waste management) whereas a formal theory is more abstract and refers to conceptual issues such as environmentally relevant behavior.

offered that enhance a more complete understanding of policy resistance or compliance respectively.

These are good reasons why it would be worth pursuing the exhausting way of diving into different disciplines in order to get an encompassing understanding of environmentally relevant behavior. However, the initial position for this study, being embedded in a broad interdisciplinary research program eased the task, since a whole community of researchers from various disciplines contributed to the understanding of environmentally relevant behavior. Therefore, the main task of this study is to analyze and structure the findings of the research program in order to develop an integrated theory about citizens' choice and preferences and public policy explaining recycling dynamics.

Hence, this study is striving to integrate knowledge and data from different disciplines and perspectives in order to explain the multidimensional factors and processes leading to the observed recycling dynamics. Aggregated human behavior effects on the recovery of natural resources from a macro-perspective are combined with individual behavior theories from a micro-perspective. Understanding both levels may yield significant clarification of environmental problems and provide a more complete basis for policy making, which is in line with Vlek's (2000) observations.

3.1.1 An interdisciplinary perspective on environmentally relevant behavior and issues

The fourth module of the SPPE was the coordinated interdisciplinary project focused on environmental awareness and activity[21]. In the following section an overview of the different disciplines and approaches that try to shed light on environmentally relevant behavior is presented. The main findings of the various projects are synthesized and structured in a way that helps to define or describe general preconditions for environmentally sound behavior. They are presented as a "heuristic" for decision-makers that aim to improve the action-opportunities for environmentally sound behavior.

Table 3.1 illustrates the different disciplinary perspectives (more than ten different ones), and issues as well as the sorts of insights that shed light on the research topic.

Author	Perspective / Discipline	Issue	Deliverables – sort of insights
(Diekmann and Franzen 1996a)	Sociology,	Perception of environmental problems, environmental concerns, individual environmentally relevant behavior	Low-High-Cost-Hypothesis
(Bütschi, Kriesi et al. 1996)	Political science	Promotion of environmentally responsible traffic behavior	A LISREL-Model explaining intention
(Jaeggi, Tanner et al. 1996)	Psychology	What are the obstacles to acting environmentally friendly?	"Ipsative" action theory
(Ernste 1996)	Sociology,	Action theory explaining	Extended theory of planned behavior

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[21] For an encompassing presentation of the findings of the project see (Kaufmann-Hayoz and Di Giulio 1996a)

	Psychology, Economy	environmentally relevant behavior	
(Fuhrer and Wölfling 1996)	Social-psychology	Explanation of environmentally relevant behavior	Theory development: Model of environmentally responsible behavior
(Mosler, Gutscher et al. 1996)	Social-psychology	What are the conditions that help increase the number of participants till the tipping point is reached and new behavior patterns may evolve?	Computer-assisted theory development
(Gessner 1996)	Psychology	Restrictions and constraints of environmentally sound behavior	A typology of constraints and restrictions
(Kyburz-Graber, Rigendinger et al. 1996)	Education science	Problem-orientation and participation as constitutive elements of environmental education	Towards a didactical concept
(Finger, Bürgin et al. 1996)	Management science	How do organizations learn to act environmentally sound?	Key elements promoting environmentally relevant learning processes
(Roux 1996)	Agricultural economics	What are effective factors in advanced training programs for farmers aiming to adopt environmentally sound production behavior?	Towards a concept of mutual learning
(Lesch 1996)	Ethics	How can ethics contribute to solve conflicts between economical efficiency and environmental responsibility?	A model of ecological and ethical discourse
(Schaber 1996)	Philosophy, Ethics	What would be an ethically appropriate relationship with nature?	Arguments illustrating the superiority of democratic decision processes over decisions based on cost-benefit analysis
(Schmid-Holz 1996)	Theology, Ethics	What would be an ethically appropriate relationship with nature?	cf. Schaber 1996
(Jäggi 1996)	Religious science	Inter-religious strategies for building environmentally responsible norms	Two strategies to push environmental norms: a context dependent and a universal strategy
(Brechbühl and Rey 1996)	Linguistics	Implications of language and cultural based differences in reports on environment and nature – a description	Ditches between the different Swiss language areas
(Thomas 1996)	Design	What is the role of pictures in the environmental debate?	Communication with pictures - important goals

Table 3.1: Disciplines, issues and sorts of insights of the SPPE-Project "Environmental Awareness and Activity".

Synthesizing the results of the more than sixteen projects, Kaufmann-Hayoz and Di Giulio (1996a) identified six main issues of environmentally responsible behavior[22]:

- Issues of values: Values as important factors inducing behavior change towards environmentally sound behavior

- Issues of awareness: Environmental concerns as necessary but not sufficient conditions for environmental sound actions (ESA)

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[22] For a description and for suggestions to improve the conditions see Kaufmann-Hayoz and Di Giulio (1996a: 509-535). For a more detailed elaboration on types of problems see Gessner and Kaufmann-Hayoz (1995).

- Issues of individual action: Preconditions for building ESA-strategies

- Issues of collective actions: Impacts of collectives on individual ESA strategies

- Issues of education and consulting: Effective learning and conveying action relevant knowledge related to environmental issues

- Issues of a cultural perspective: Cooperation and communication between different cultures on environmental issues

The research findings give evidence that it is crucial to analyze the preconditions for the target behavior change for effective policy design. Thereby we can distinguish conditions within a person (e.g. values, goals, attitudes) from conditions in the context respectively in the specific situation (e.g. the existence of ESA alternatives):

Contextual preconditions include interpersonal forces, distinctive features of substitutes, existence of different action alternatives and technologies, and design, as well as infrastructures, monetary incentives and costs, as well as legal regulations.

Personal preconditions include forces influencing values, beliefs, attitudes, goals, self-identity, knowledge and skill, as well as general capabilities such as literacy.

However, the literature review of the above-presented interdisciplinary research resulted in a list of potentially relevant preconditions for environmentally sound behavior. The aim is to package the findings of the literature review in a way that is thought to be useful for both policy-making and theory-development indicating important variables and the direction of impact. In order to fulfill both functions they are presented as *"A List Of Important Criteria for Public Policy"* that policy makers should consider. In order to improve a precondition, measures should aim to fulfill the mentioned criteria. Measures are defined as interventions that change the precondition directly or indirectly. In the former case the measure may fulfill the criterion itself; (e.g. offering services for solid waste separation contributes directly to the criterion "creating environmentally friendly action alternatives"). In the latter it aims at processes that contribute to the criterion; (e.g. exhibitions about compost and soil quality contribute indirectly to the criterion "promoting personal communication in social groups on ESA alternatives").

A List of Important Criteria for Public Policy

A) Improving contextual preconditions

In order to facilitate environmentally sound behavior measures should help ...

... promote personal communication in social groups on ESA alternatives
... reduce the risk that environmentally sound behavior will be socially sanctioned or punished
... encourage cooperation, participation, and voluntary agreements on environmental targets
... make ESA alternatives salient and attractive
... create ESA alternatives by reinforcing, and/or facilitating structures, and weakening inhibiting ones

... promote primarily those alternative products or services, which are neutral in costs and
    time demands

... reduce high costs for the target groups

... encourage farsighted planning, which converts high-cost situations into low-cost
    situations

... respect personal autonomy

... respect the level of environmental awareness in the community

... respect prevalent normative and moral trends

B) Improving personal preconditions

In order to facilitate environmentally sound behavior measures should help ...

... facilitate unhindered and adequate perception of environmental problems

... visualize environmental problems and risks

... deliver information about ecological facts in an understandable way

... touch emotional, natural, social, economic, and historical aspects of environmental issues

... point out information on energy and resource efficiency of appliances and durable goods

... promote discussions on factual issues as well as on diverging interests and visions on
    occasions of referenda and new actions on environmental policy issues

... measure and communicate parameters of environmentally relevant behavior directly to
    the user / polluter

... point out causal effects of own and others' behavior and their short- and long-term
    consequences

... point out the factors and processes, which influence environmentally undesired behavior

... promote primarily those alternative products and services that are equally convenient as
    conventional ones

... point out the value and attractiveness of ESA

... focus attention on undesirable routine behaviors and break corresponding structural
    constraints

... complicate environmentally undesirable behaviors, thus making them less attractive

... modify structures of production, distribution, and housing, which generate harmful
    environmental side-effects e.g. high transport needs

... avoid strong negative emotional reactions

... create personal commitment

... contribute in a general way to a transformation of the environmentally relevant living
    situations such that environmentally sound lifestyles are favored.

It may be trivial to assume that if the various conditions could be improved by measures within the community then more environmentally sound behavior patterns would evolve. For decision-makers it seems to be more important to know, which the decisive missing conditions are and which interventions seem to be most effective given the specific conditions. These issues will be addressed in the main study.

3.1.2 Personal and contextual factors

The previous statements derived from research on environmentally relevant behavior suggest that changing personal and situational preconditions may help steer individuals' behavior toward environmentally responsible behavior. In the following section two frameworks that are in line with the focus of this study - aiming to shed light on interactive effects between changes in personal and situational conditions - are presented.

Stern (1999) suggests a framework for environmentally significant behavior in which he distinguishes the personal, situational and the behavioral domain of environmentally relevant behavior.

The *personal domain* includes individuals' basic values, their beliefs (e.g. their beliefs on how the biophysical environment functions and responds to human action, and the social pressure on them to behave in the "right way") and moral normative beliefs (e.g. environmental attitudes). Stern refers to the Value-Belief-Norm (VBN)-Theory (Stern, Dietz et al. 1999) that expands Schwartz's theory of altruistic behavior (e.g. Schwartz 1977) and explains how the various elements interact and how they affect the individual level of support for the goals of social movements including environmental initiatives. This theory suggests an explanation why a rational utility calculus presumed in subjective expected utility model might be bypassed or truncated.

The *contextual domain* includes diverse settings reaching from cultural background, economic situation and education to the immediate situation, constraints, and opportunities, for example stemming from public policy decisions.

In the *behavior domain* different types of behavior are specified (e.g. committed activism and private-sphere behaviors) but also interactive effects between variables of contextual and personal domains:

> *"The evidence suggests that from a predictive standpoint, the likelihood of a behavior occurring depends on forces – both personal and contextual – that impinge on an individual in the context of the choice of whether to engage in a particular behavior at a particular time"* (Stern 1999:464).

Stern (1999) hypothesizes and illustrates with empirical experiments an inverted U-shaped relationship between contextual forces and the strength of attitude-behavior relationship (e.g. referring to interactions between information and incentive strategies). "The weaker the contextual forces, the more personal-domain variables are likely to matter" (466) and vice versa. He concludes that price elasticity of demand can be influenced by informational components of a policy. Stern's theoretical approach has important analogies to the one pursued in this work. This holds especially for the focus on personal and contextual variables as driving forces and their interactions explaining support of environmental initiatives. Stern's approach, however, also shows the limits of a descriptive, qualitative theory to illustrate and explain the hypothesized interactions and their impact on policy effectiveness.

The Ipsative[23] Action Theory offers another approach explaining interactive effects of personal and contextual conditions and constraints (Foppa and Frey 1985; Foppa and Frey 1986; Foppa and Frey 1990, Tanner 1999). This theoretical approach tries to integrate psychological and economic concepts into one choice framework (Ulli-Beer and Kaufmann-Hayoz 1998), which shows that not only the rational choice logic but also the preconditions determine behavior. A critical appraisal of this approach can be found in Vatter (2000). In the Ipsative Action Theory, two main sets of action possibilities are identified: objective, real sets of action possibilities, and subjective or ipsative sets of action possibilities. They are either determined by imperfect information about the objective action set (perception bias, subjective action set) or, by individuals' psychological processes shaping the subjectively and ipsative relevant action set in the specific situation. Tanner (1999) builds on this theory and distinguishes three types of constraints with different functions as described in Table 3.2.

Type	Ipsative constraints	Subjective constraints	Objective constraints
Function	Preventing activation of particular behavioral alternatives	Preventing preferences for particular alternative	Preventing performance of particular behavioral alternatives

Table 3.2: Types of constraints for environmentally responsible behavior (adopted from Tanner 1999:147).

In order to elaborate concrete measures against constraints of environmentally relevant behavior it may be very important to distinguish between all three kinds of constraints, especially considering the ipsative constraints that may be crucial in the specific choice context. However, for the development of a policy analysis model a focus on the subjective and objective constraints may be more promising since they are more persistent.

While the two approaches described above attempt to offer an integrative theoretical framework describing environmentally relevant behavior, another conceptual approach is to focus on behavior through different theoretical perspectives and to assess their relevance for the specific behavior class. The following section illustrates such an approach and portrays a list of key concepts.

3.1.3 Key concepts and building blocks explaining environmentally relevant behavior

A systematic approach to analyze a specific issue from various perspectives is the identification of *key concepts* that may be useful in order to shed light on observed phenomena[24]. Gessner (1998), Vatter (2001), and Wittwer (2000) applied this approach exploring environmentally relevant behavior. At the initial point of their research they identified and described twelve key concepts mainly based on psychological theories. Their

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[23] Ipsative means that each person provides his or her own reference

[24] Glaser and Strauss (1967:38) describe them as analytical and sensitizing concepts ("analytische und sensibilisierende Konzepte") that are seen as an efficient way to organize a perspective-triangulation in (Flick 1995:153).

research evidence, however, suggested the importance of an additional one – formation of habits (see Table 3.3).

Key-concept	Assumptions / Explications
Value-orientation (Wertorientierung)	Environmental value-orientation is seen as a main condition for an environmentally intended actions
Control beliefs (Kontrollattribution)	Individual beliefs about own action possibilities and self efficacy as a precondition for environmentally responsible actions
Perception of unintended consequences (Nebenfolgenwahrnehmung)	The awareness of un-intended, distant and delayed consequences
Risk-perception (Risikoperzeption)	Individual evaluation of environmental risks as a precondition of environmentally responsible behavior
Formation of intention (Intentionsbildung)	Development of an intention to act in an environmentally sound way (as a result of interactions of personal and situational factors)
Dynamics of prognosis (Prognosedynamik)	Individuals prospective of the impact of own and others' actions on the natural environment
Human error (Menschliches Versagen)	Limited mental capacities to understand complex dynamics may cause "wrong" choices and actions
Structural constraints (Struktureller Zwang)	Objective constraints of individuals' action-possibilites caused by situational factors
Self-management (Selbstmanagement)	Designing its own action frame in order to ease (constraints) environmentally sound (destructive) actions
Perspective taking (Perspektivenübernahme)	Understanding of other people's cognitive processes and states
Prosocial orientation (Prosoziale Orientierung)	Individual alignment with social norms relating to collective action-situations
Collective actions (Kooperatives Handeln)	Framing of environmentally significant actions in collective settings
Habit formation (Gewohnheitsbildung)	Habits as unfavourable personal preconditions for environmentally sound behavior since they do not enter into deliberation processes

Table 3.3: Key-concepts for environmentally responsible behavior (see Bruppacher 2001a, Gessner 1998, **Vatter 2001**, Wittwer 2000).

For the empirical investigation of environmentally responsible behavior, participants of the self-modification program GAP (Global Action Plan for the Earth)[25] were asked to complete a survey (N=60). The key concepts proved to be useful for characterizing their values, their perception and evaluation of environmental problems, as well as their intention to act environmentally friendly. Furthermore, perceived goal conflicts, as well as participants' beliefs in the necessity for further policy measures facilitating environmentally friendly action alternatives could be elicited. Especially interesting results were highlighted by the key concept of **collective actions**. Although the sample perceived subjective dilemma situations – missing cooperation of other people – they would try to act in an environmentally friendly manner anyway. Furthermore, they emphasize that if more people were cooperative this

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[25] GAP is an international environmental association that was founded in 1990 in the USA. They offer environmental programs for households, schools, corporations and municipalities. Findings substantiate the assumptions that participants of this program have strong environmental concerns (Graf 1997, Bruppacher 1998). Therefore this population is considered especially suitable for the investigation of barriers hindering the implementation of environmentally friendly intentions. For a further description see (Bruppacher 2001a), (Wittwer 2000).

would increase their own intention even more. Additionally, they not only mentioned perceived social constraints but also high cost situations. They reported that although they are able to overcome those constraints, for other people those might be insurmountable (Vatter 2001).

A preliminary explorative statistical analysis (factor analysis) of the operationalized key concepts gives evidence of at least three distinguishable variable complexes. They can be described as a **cognitive / evaluative variable complex,** a **situational-restrictive variable complex** and an **intention related variable complex** describing environmentally responsible behavior (a specification of the different complexes is given in Vatter (2001)). Another workshop-based exploration[26] of environmentally responsible behavior of GAP-participants suggests that daily environmentally relevant behavior of households can rarely be described by error-theoretical concepts (Wittwer 2000). However, in the mentioned study further „concepts in use" explaining constraints of environmentally relevant behavior were highlighted, such as convenience, "mobility-addiction", social dilemmas, market structures, individualisms, time-constraints, and advertisement.

Habits as a latent key concept

A latent key concept explaining environmentally relevant behavior seems to be the one of habits and routines. According to Scitovsky (1989) people are often not aware that most of their behavior is determined by habits. They would rather mention the initial motives forming the habitual behavior. However, Piorkowsky (1988) speculates that 80% of household behavior is either based on habits and tradition or routine behavior. Such a behavior is often unconscious but economical since it does not require sophisticated deliberation processes. A Professor of Neuroscience argues that "we all live mostly by habits,..., and automatic learned responses such as those used in driving and bike-riding – may serve to free up the "thinking" parts of the brain for more creative purposes" (Halber 1999).

This convenient way of behavior has the drawback that people may not adjust their habits to changes in the context. Furthermore, Dahlstrand and Biel (1997) highlight the trade off between attitude and habit. "When habit is strong, the attitude – behavior link is weak; whereas when habit is weak, the attitude-behavior link is strong" (588) referring to Verplanken, Aarts et al. (1994). Therefore, changing well-established habits may be hard. Concerning environmentally relevant behavior, routine behavior may be functional but may also have unintended environmental impacts. Gorr (1997) observed such a situation in traffic behavior: only 5% of car-owners make some deliberation between different means of travel. Also Känel, Magun et al. (1998) showed that the concept of habit may be significant for explaining environmentally relevant behavior. Dahlstrand and Biel (1997) suggest processes that help unfreeze old habits and to establish new more environmentally sound habits. First attempts to include the concept of habits in a broader theory explaining

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[26] The used workshop-method is called "Zukunftswerkstatt" developed by (Jungk and Müllert 1989).

environmentally relevant behavior can be found in Bamberg, Biel et al. (1995); Bamberg (1996), Aversi, Dosi et al. (1997), Wendner (2002), Dietz and Stern (1995), Dahlstrand and Biel (1997), Bruppacher (2001a), Kaufmann-Hayoz (1998) and Klöckner, Matthies et al. (2003).

3.1.4   Preliminary implications for the model development

Based on this literature review some first assumptions for the model development can be summarized.

Basically two sorts of preconditions for environmentally responsible behavior can be distinguished: **contextual, situational preconditions** (such as time constraints, costs, or social influences) and **personal preconditions** (such as attitudes, goals, norms, self-identity). The contextual preconditions are influenced by situational, restrictive variables and the personal preconditions are influenced by cognitive, evaluative variables. Both variable complexes influence intention-related variables guiding actions.

"Preconditions for environmentally responsible behavior" seems to be a relative concept, being evaluated subjectively: in other words, there may be a trade-off between the impact of constraints on behavior and environmental concerns or social norms. Higher environmental concerns depreciate the perception of constraints and obstacles, whereas lower concerns tend to reinforce action constraints. Furthermore, high environmental concerns seem to increase the effort and the willingness to spend time and costs on environmentally sound behavior. Similarly, social support seems to increase the effort and the willingness to spend more time and costs on environmentally sound behavior in order to overcome hurdles.

However, often habits dominate observed behavior patterns of people and deactivate deliberation processes. Unfreezing such habits may be a tedious and time-consuming process.

3.2   Psychological   theories   and   concepts   explaining environmentally relevant behavior – identification of a research gap

Since environmental problems are caused by human behaviors, psychological concepts are seen as highly relevant in order to structure the observed phenomena and to explain environmentally relevant behavior at the individual level. Their strength is a well-built source of different concepts and theories offering cause and effect explanations. Stern (2000) concludes:

> *"(M)ethodologically, it is the strongest of the human sciences in the use of experimentation and thus is in the best position to clarify issues of cause and effect, such as the limitations of single-variable explanations. Theoretically, it is the source of several useful ways of understanding how people interpret information about their environment and how they respond on the basis of these understandings" (529).*

He also observes that the human impact on the environment results from interactions of various driving forces. Referring to Derksen and Gartell (1993) and Guagnano, Stern et al. (1995) he concludes, "studies of recycling programs have revealed that the strength of attitude-behavior relationships depends on external conditions affecting the ease of engaging in the behavior" (529). In order to explore those, some disciplinary presumptions need to be questioned and new theoretical approaches may be considered as necessary. He identifies research opportunities that arise from a critical look at beliefs about human-environmental interactions and summarizes them in the following Table 3.4.

Belief	Evidence	Research opportunities
Individual choice	Importance of individuals depends on the environmental problem, but is usually less than half	Focus where individuals matter most; examine influences on organizational behavior and public policy
Consumption	Production may be at least as important; not all types of consumption are environmentally equivalent	Focus on environmentally significant consumption, on consumers in developing countries, on green consumption that affects producers' decisions
Sacrifice	Usually less effective than adopting green technologies	Study purchase decisions for consumer technology
Values and attitudes	Effects are typically weak except in interaction with other forces	Study interactive effects of values, attitudes, beliefs, information, incentives, motivational appeals, social pressures, and so on in particular behavioral contexts
Education	Same as for values and attitudes	Same as for values and attitudes
Motivation	Same as for values and attitudes	Same as for values and attitudes
Incentives	Very important, but dependence on other factors is little understood	Same as for values and attitudes
Emulation	Effects are largely unknown	Study effects of mass media exposure on consumption behavior and intentions

Table 3.4: Beliefs about human-environmental interactions, comments on their accuracy, and research opportunities arising from a critical assessment (Stern 2000:528).

The approach of this study tries to exploit some of the identified research opportunities illustrated in the table above and is in line of the future research directions for tackling with environmental problems proposed by Vlek (2000) and Stern (2000). The present research can be seen as an innovative approach organizing and analyzing interactive effects of personal variables such as values, attitudes (preferences), and situational variables such as social pressures, time and monetary costs in the particular behavioral context of waste separation behavior at the local level. It relates to psychological theories and the findings of empirical experimental studies explaining separation behavior of citizens. As stated earlier on, the motivation of applying psychological concepts is to provide a more complete basis for policy making (see also, Vlek 2000).

A further important research line identified by Vlek (2000) supports investigating environmental policy formation and decision-making:

> *"Here one would serve the policy makers' perspectives on the assessment and management of environmental risks. This requires adequate definitions of environmental quality, models for structuring policy decision problems, and methods for capturing experts' judgments"* (163).

This study is seen as a step in this direction that helps both to structure policy-decision problems and to include the perspective of the experts on the respective system.

Stern (2000) suggests an encompassing theoretical framework explaining environmentally significant behavior that helps both to situate the current work and to substantiate its explorative model building process. According to this framework (see Table 3.5) the current study deals with private-sphere environmentalism and searches for essential causal variables explaining environmentally significant behavior in general and in the specific case of citizens' disposal behavior.

Principles for intervening to change environmentally destructive behavior	Types of environmentally significant behaviors		
A: Use multiple interventions to address the factors of behavior change • Limiting factors are numerous • Limiting factors vary with actor and situation, and over time • Limiting factors affect each other	Private-sphere environmentalism • Consumer purchase behavior • Maintenance of household equipment use, lifestyle • Waste disposal behavior • Green consumerism	Environmental activism • Environmental citizenship (e.g. petitioning, joining groups, policy support)	Other Behaviors affecting organizational decisions
B. Understand the situation from the actor's perspective			
C. When limiting factors are psychological, apply understanding of human choice processes • Get the actors' attention, make limited cognitive demands • Apply principles of community management			
D. Address conditions beyond the individual that constrain proenvironmental choices	Attitudinal General environmentalist predisposition, behavior-specific norms and beliefs, non-environmental attitudes, perceived cost and benefits of action		
E. Set realistic expectations about outcomes	Personal capabilities Literacy, social status, financial resources, behavior-specific knowledge and skills		
F. Continually monitor responses and adjust programs accordingly	Contextual factors Material costs and rewards, laws and regulations, available technology, social norms and expectations, supportive policies, advertising		
G. Stay within the bounds of actors' tolerance for intervention	Habits and routine		
H. Use participatory methods of decision making			

Table 3.5: Principles for inducing behavior change, types of environmentally significant behavior and causal variables influencing these kinds of behavior (adopted from Stern 2000:420/1).

However, this work goes a step further than Stern's framework, since the focus of interest is not mainly on the micro-process as the end but "lies instead in the act of synthesis, in beginning to show how the micro processes combine to constitute a functioning system" as was already suggested by Coleman (1965:91), 40 years ago.

Gresele (2000) describes an antipodal but sophisticated psychological approach investigating the influence of contextual and social situational factors, as well as the interaction with personal characteristics (such as social needs, age and gender) influencing environmentally relevant behavior. Her findings suggest that motivational factors are less influential than specific combinations of contextual, and social and personal characteristics.

3.2.1 Descriptive and normative theories of decision-making

Different disciplines aim to understand and predict behavior or actions, of individuals and organizations, respectively. The focus is mostly on the decision making process while other behavior phenomena like habits and routine behavior are neglected (see Kaufmann-Hayoz 1998). This is one general critique point one should be aware of, when studying action-theories. However, recent literatures aim to integrate further concepts. For example Dietz and Stern (1995) suggests the following choice concept.

> *"We exclude coerced behavior but recognize a continuum from nearly automatic, unconsidered behaviors, such as habits, to carefully deliberated choices, which are commonly labeled decisions. Most human action of interest is neither habitual nor fully deliberated. It involves some degree of consideration contemporaneously or at some time in the past"* (262).

Moreover, we have to distinguish between two types of decision theories – either referring to a normative or to a descriptive understanding. Kahneman and Tversky (2000:1) describe both as follows:

> *"The study of decisions addresses both normative and descriptive questions. The normative analysis is concerned with the nature of rationality and the logic of decision making. The descriptive analysis, in contrast, is concerned with people's beliefs and preferences as they are, not as they should be"* (1).

In this work we try to understand how citizens will decide in a specific situation. This implies a descriptive decision-rule. Having a consistent decision-rule enables us to predict actions in the future. This is especially relevant to understanding the impact of policy interventions. Therefore, the applied logic of the decision rule also determines the application range for analyzing different intervention strategies. For example, the economic utility maximizing approaches mainly offer a policy analysis-framework for economic and command and control intervention strategies. Including attitudinal and personal variables in the decision rule provides a broader basis for policy analysis. Intervention-strategies taking into account those variables are seen as especially relevant to local attempts to induce behavior change towards environmentally sound lifestyles. Therefore, psychological decision-theories are seen as important for building and grounding adequate decision-rules.

In this work the separation behavior of citizens is seen as a result of a combination of a simple but deliberate decision process including social influences, personal and contextual factors, as well as habitual behavior. Especially, in the context of policy compliance situations such an understanding is seen as reasonable, since policy initiatives often aim to create a social norm behavior. Citizens in turn will judge the outcome of desired separation-behavior against their values and goals. In the case of waste separation behavior either egoistic or altruistic value clusters could be used as evaluation criteria. In the following paragraph some basic psychological action theories are described that are evaluated as relevant to separation behavior.

3.2.2 The theory of planned behavior and environmentally relevant behavior

An important and empirically well-supported theory explaining and predicting human behavior in specific contexts is the theory of planned behavior (Ajzen and Fishbein 1980; Ajzen 1991, Ajzen and Madden 1986, Ajzen 1988). According to this theory, the behavior can best be predicted from a person's intention to perform the behavior. The intention in turn is a function of three components: an attitudinal component (attitude toward the behavior), a normative component (subjective norm), and a control component (perceived behavioral control). It is an extension of the original theory of reasoned action (Ajzen and Fishbein 1970), additionally taking into account that barriers and facilitating conditions influence the intention. Perceived behavioral control refers to people's perception of convenience of performing the behavior of interest. Resources and opportunities available to a person will influence the likelihood to perform the behavior. Figure 3.1 illustrates the main postulated relationships of this theory.
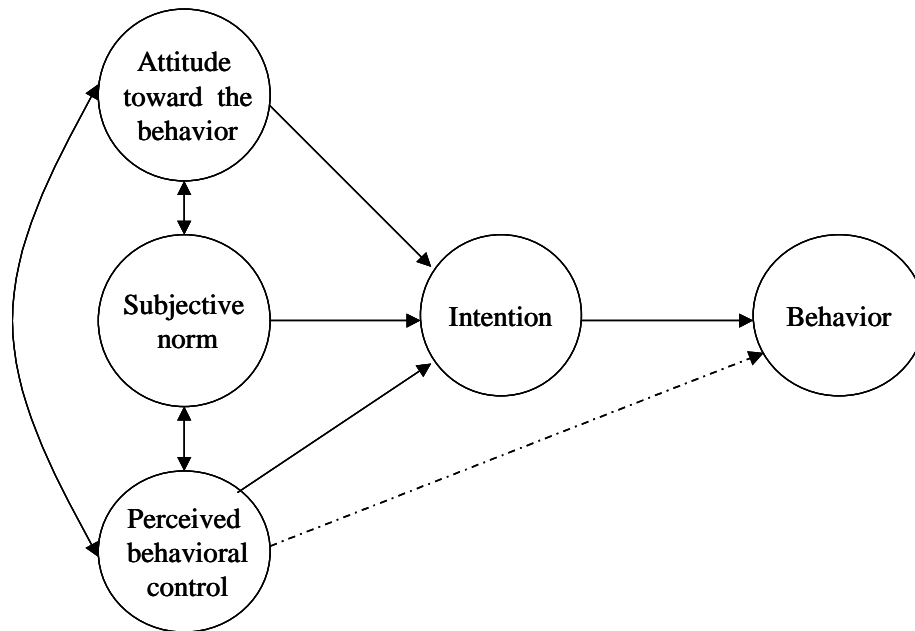

Figure 3.1: Structural diagram of the theory of planned behavior ("Reprinted from Organizational Behavior and Human Decision Processes, Vol 50. 1991, Ajzen 'The theory of planned behavior':182, Copyright 2004, with permission from Elsevier").

In addition to this structural representation of the theory of planned behavior, Ajzen (1991) suggests "at the most basic level of explanation, the theory postulates that behavior is a function of salient information, of beliefs, relevant to the behavior... It is these salient beliefs that are considered to be the prevailing determinants of a person's intention and actions" (189).

In order to understand the determinants of consumers' composting behavior Taylor and Todd (1997) compare three models of waste management behavior: a theory of reasoned action model, an environmental belief-behavior model, and an integrated waste management model, which is based on the theory of planned behavior but also incorporates the belief components. The study's results show that the integrated waste management model provides better predictive power than the other two models. Furthermore, it offers additional insights into factors that influence attitudinal beliefs, normative beliefs and control beliefs. Table 3.6 specifies the three beliefs concepts for behavior associated with composting:

Attitudinal beliefs	Personal relative advantages	Represent perceived personal benefits such as monetary savings
	Societal relative advantages	Represent perceived collective benefits such as saving natural resources
	Complexity	More favorable attitudes toward a novel behavior will result when perceived complexity is low
Normative beliefs	Internal normative beliefs	Internal normative beliefs with respect to family
	External normative beliefs	External normative beliefs with respect to friends and neighbors
Control beliefs	Self efficacy	Perceived ability to carry out the behavior, perceived effectiveness, knowledge
	Resource facilitating conditions	Perceived accessibility of resources of facilities to carry out the behavior
	Compatibility	Including compatibility issues such as perceived inconvenience, effort, time, cost

Table 3.6: Decomposed belief structures (adopted from Taylor and Todd 1997:608/9).

Figure 3.2 shows the extended theory of planned behavior with the decomposed belief structure applied in the integrated SD-SWM-model.
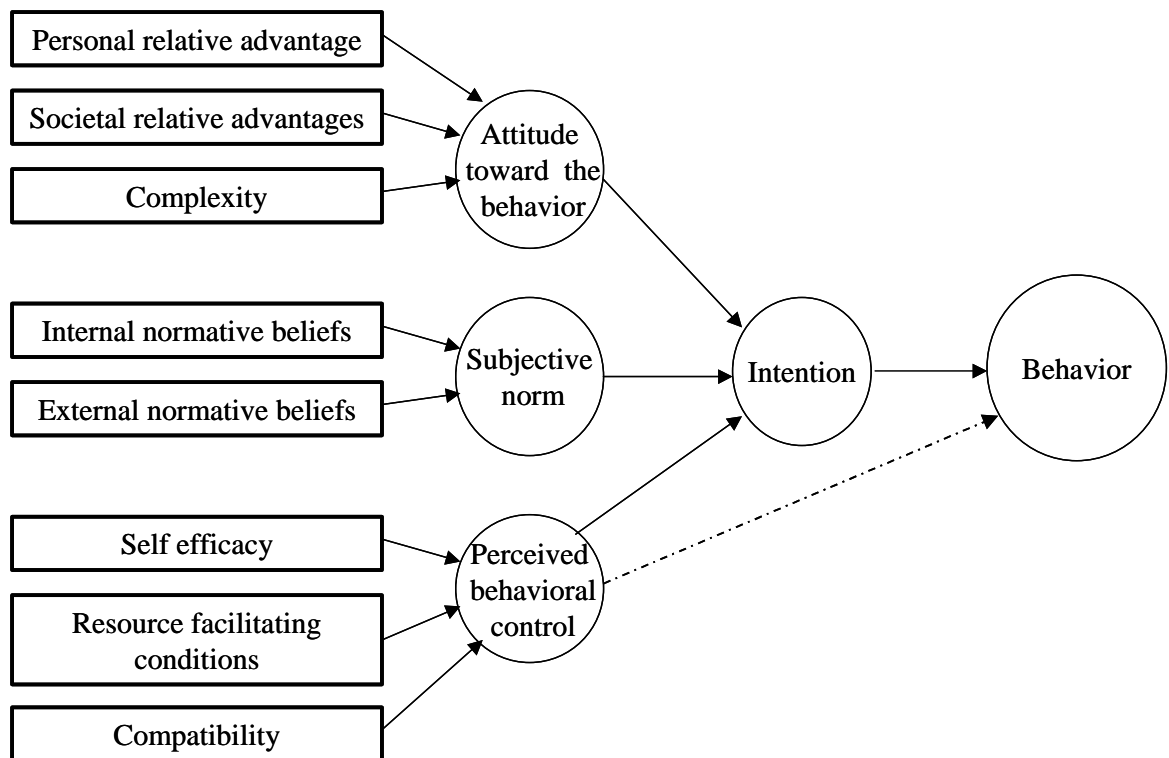

Figure 3.2: The integrated waste management model (adopted from Taylor and Todd 1997:611).

Based on the findings that intention was strongly determined by attitude and perceived behavioral control the authors suggest that policymakers should concentrate primarily on mechanisms to influence those two variables. More specifically the societal relative advantage was an important key determinant of attitude. Therefore, it is suggested that policymakers should stress societal benefits of composting behavior. Contrarily, personal benefits may negatively influence attitude toward compost behavior. Similarly, complexity also had a negative influence. Therefore, policymakers should attempt to reduce the perceived complexity of waste management activities. Moreover the three determinants of perceived behavior control were positively related. Therefore, the authors suggest that policymakers should focus their efforts on making the necessary resources available and on ensuring that the activities are not perceived as too time consuming.

Terry, Hogg et al. (1999) applied the theory of planned behavior also in the setting of recycling behavior. One aim of the study was to examine the combined effects of self-identity and social identity constructs on intention and behavior. The study gives evidence that the perceived norm was only relevant to people who identify strongly with the group and that for low identifiers the relationship between the perceived behavioral control and intention was strongest.

3.2.3   Social norms and behavior

According to Coleman (1991) externalities make the emergence of social norms desirable. Social norms describe standards of behavior prescribed and sanctioned by a community and constitute a frame of reference for social interactions that involves expectation about the "appropriate" behavior in a given situation. Different authors of social science adopt this definition of social norms, such as Coleman (1994), Opp (1982), Kahneman, Knetsch et al. (1986), Haagsma and Koning (1999). Hence, in sociology social norms are seen as guidelines that help cope with externality in a socially acceptable way.

Biebeler (2000) suggest a stronger value oriented understanding of social norms. He highlights that social norms are an uncertainty factor in forecasting behavior, if only the situational factors are known and nothing is known about people's minds. In Biebeler's definitions of individual norms, evaluative cognitive processes and beliefs are included (15). He reports case studies in which 26% of the variance in intention and 37 − 49% in behavior can be explained by social norms.

The influence of social norms on behavior has a long history within social psychology. Latané (1981) proposes a general theory of social impact. According to this theory the social impact is seen as a social force on an individual that can be specified by a multiplicative function of the strength (S), immediacy (I), and the number of other people (N).

$$\textit{Social force, } I = f(SIN)$$

He specifies the relationship with a *psychosocial law* that postulates a marginally decreasing effect of an increased supply of people. The amount of social impact (*I*) a person will experience from a group of people equals some power (t), of the number of people (N) multiplied by a scaling constant (s).

$$\textit{Social force, } I = sN^t, t < 1$$

Based on empirical experiments he shows that this relationship can be observed in many domains and that it encompasses a variety of processes. However, the extensive literature about social norms shows that its predictive value is controversial[27]. In order to clarify the role of social norm Cialdini, Reno, and Kallgren propose a focus theory of normative conduct (Cialdini, Reno et al. 1990; Cialdini, Kallgren et al. 1991, Reno, Cialdini et al. 1993), in which they distinguish between two types of social norms: the *descriptive norms* on the one hand, specify what is typically done, and motivate action by informing people of what is seen as an effective and adaptive behavior in a particular situation. On the other hand *injunctive norms* specify what people approve and disapprove of in a society, and motivate action by promising social sanctions for normative or counter normative conduct. Series of empirical experiments testing the social norm against littering give evidence that focusing people's attention on injunctive norms has a greater utility for increasing socially desirable behavior under most circumstances. However, in settings where most people already behave in a

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[27] For a distinction of the literature in two camps either arguing that social norms are crucial to a full understanding of human social behavior or that the concept is too vague and too overly general, see Cialdini, Reno et al. (1990).

socially desirable manner, activating the descriptive norm is likely to enforce the socially desirable behavior[28].

A further important model explaining the role of norms on behavior is Schwartz's *altruism model* (Schwartz 1968; Schwartz 1973; Schwartz 1977; Schwartz and Howard 1981; Schwartz 1994). By definition *altruistic behavior* is a normative behavior that is guided by social norms. An important characteristic of altruistic behavior is that many people would verbally agree to a norm guiding moral behavior but not every one would do so. Therefore, the model tries to explain under which conditions altruistic social norms translate into behavior. According to the altruism model existing social norms, general existing norms on the social level representing the values of significant others, would be transformed into personal norms, seen as moral attitudes on the individual level (see Schwartz and Howard 1980). However, those personal norms will only be activated when they are assessed as relevant and applicable to the specific situation. In the model two variables are relevant to this evaluation process: *the awareness of consequences* and *the ascription of responsibility*. When both are high, personal norms will be translated into behavior.

Based on evidence of previous empirical research, Hopper and Carl-Niesen (1991) conceptualized recycling behavior as altruistic behavior (see Figure 3.3).
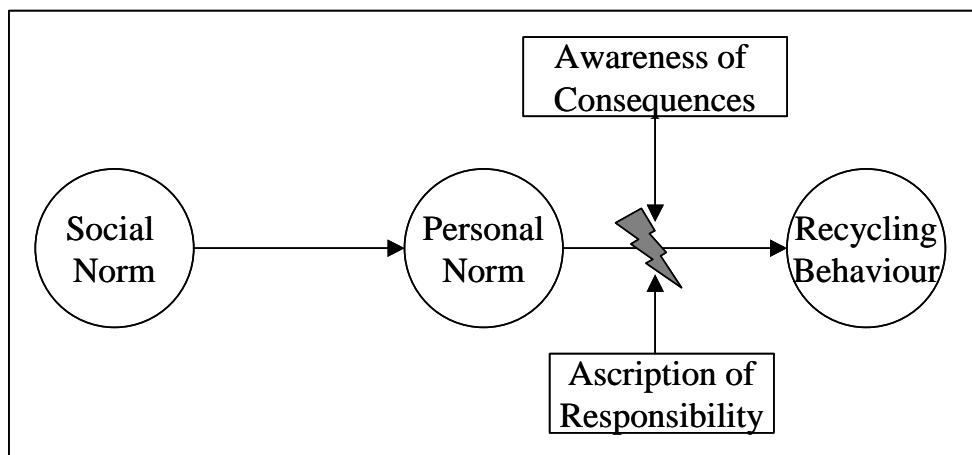

Figure 3.3: Recycling behavior as altruistic behavior (adopted from Hopper and Carl-Niesen 1991:200).

Using a cognitive/normative approach in an elaborated field experiment the authors could give further evidence that firstly, recycling is a form of altruistic behavior, in which the perceived social norm to recycle influences behavior through the intervening personal norm to recycle but only when the awareness of consequences were high. Secondly, the data indicate "that more than simple reminders and informational brochures are necessary to

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[28] For a comprehensive description of the experimental studies, see for example Reno, Cialdini et al. (1993).

influence attitudes. A social intervention that taps into the very processes through which norms are shaped is crucial" (Hopper and Carl-Niesen 1991:215).

Those psychological theories suggest that social norms play a relevant role in explaining (waste separation) behavior. However, they were often neglected in policy analysis approaches. But contemporary, innovative economists, for example Akerlof (1980) or Haagsma and Koning (1999), start including social norms in their economic decision calculus and explaining phenomena like the persistence of non-market clearing wages, collective strike action, or crowding and sub optimal prices in agriculture. Other economists refer to the existence of social preferences when explaining competition and cooperation or successful collective actions (for an overview see Fehr and Schmidt 1999, Fehr and Schmidt 2000, Fehr and Fischbacher 2002).

In the present work the concept of social norm and its influence on citizens' separation behavior is one important postulated relationship. While the different psychological and economical theories and models illustrate the variety and controversy about this issue, the empirical studies give empirical support of its relevance for explaining behavior in different contexts. In the SD-SWM-model social norms are incorporated as one force determining the decision rule.

3.3   An economic perspective on household choice and environmental policy

Economics is the discipline that combines the virtue of science and politics (Mankiw 1998) helping both to manage scarce resources and to improve social welfare. Therefore, in this chapter some relevant economic concepts are mentioned and it is discussed how they relate to the present work. The discussion includes micro-issues, such as household choice questions, but also macro-issues such as social welfare and externalities caused by individual choices that affect other people who are not participants of the present-markets (e.g. the future generation).

Furthermore, it is shown how the System Dynamics approach is complementary to the economic perspective and how it can generate additional insights. Although a System Dynamics model (SD-model) differs from traditional economical models in its overall nature, since it aims to explain observed phenomena and not only to describe them, it has some analogies and relates to some concepts an economist may feel familiar with. Especially, the concept of preferences and its approach to measure them with prices or the willingness to pay (WTP) may be familiar.

3.3.1   The theory of consumer choice

Positive economics, such as consumer demand analysis, is mainly interested in explaining and describing phenomena such as patterns in terms of price and income elasticity. But the economic theory including consumer choice is interpreted as both positive and normative; it gives advice on how economies should be designed and with which choices and policies it is

more likely to reach a social optimum. But it also serves as a descriptive theory e.g. aiming to describe individual choices. But in doing so, it is criticized for neglecting existing systematic errors that may lead to biased predictions (see Thaler 2000).

The theory of choice uses various forms of equilibrium analysis in order to predict what action will be selected and what result will ensue. Kreps (1990) describes the decision process using the concept of feedbacks:

> *"Individuals make individual choices, and the institutional framework aggregates those actions into an aggregate outcome which then determines constraints that individuals face and outcomes they receive. If individuals take a "trial shot" at an action, after the aggregation is accomplished and the feedback is fed back, they may learn that their actions are incompatible or did not have quite the consequences they foresaw. This leads individuals to change their individual actions, which changes the feedback, and so on. Equilibrium is a collection of individual choices whereby the feedback process would lead to no subsequent change in behavior" (6).*

Krep's feedback view illustrates nicely the processes leading to equilibrium that are implicitly incorporated in the economic theory. However, the economic theory would not explain the process but only describe the equilibrium state. In contrast, System Dynamics highlights the processes leading to equilibrium. One main element of the present SD-SWM-model explicitly formulates a theory of citizens' choice explaining those dynamics.

In economic decision theories preferences are an important concept; soft psychological variables such as "taste, need or attitude" are integrated into the mathematical formulation of the utility function or the demand function, respectively. Conventionally, it is assumed that preferences are coherent (i.e. stable, context-independent and internally consistent). Subjective preferences of the consumer but also characteristics of the goods itself determine the utility of a good. Conversely, from the welfare perspective, preferences are interpreted as a measure of the individual's welfare. Following the economic choice theory the consumer will choose the consumption bundle that will maximize his utility. The theory argues that given a free market system, "self –interest" motives will lead to a social optimum (a pareto optimum), i.e. the invisible hand or the market forces such as prices will coordinate the individual decisions in an efficient way (Smith 1964 (repr.)). However, the terms utility maximizing, and subjective reference values such as self-interest motives are often criticized. Gary Becker's often quoted statement: "Individuals maximize utility as they perceive it, whether they be selfish, altruistic, loyal, spiteful, or masochistic" (Becker 1993:386) illustrates the broad interpretation of the concept of utility.

However, since it is often assumed that the preferences are fixed and changes in behavior are explained by the budget concept, economics is traditionally not interested in explaining preference construction or changes. Therefore, its main challenge is to find an way to formalize and operationalize this construct. Typically the utility function is defined as a function that is maximized by individual actions, or by the observed consumption patterns, respectively.

J. Bentham (1748-1832) and other utilitarians were convinced that utility could be measured in terms of money – or the *willingness to pay* or to *accept*. Those concepts are

important for welfare economics and benefit-cost analysis. The term *willingness to pay* describes the price an individual is willing to pay to acquire some goods or (environmental) services. It is the source of the demand price. In economic empirical studies revealing preferences, the potential demand for products or services were measured by asking consumers, whether they would purchase this product if it were offered at this price, or how much they would be willing to pay for specific environmental services. Conversely, *willingness to accept* describes the price that someone is willing to accept to give up a good or a service. It is the source of the supply price.

However, many economists, psychologists and sociologists do not trust the price estimates that result from those surveys. Additionally, these prices are often not accepted by judges and policy makers (Becker 1993)[29].

Hence, in the economic literature the further development of the preference-concept is intensively discussed, dealing with issues like:

- Preferences that are conditional on reference points (Munro and Sugden 2001, Tversky and Kahneman 1991).

- The challenge for future research estimating both the impact of differences in preferences and constraints that include results of personality psychology (Caplan 2003).

- Respecting individual preferences including information on individual motives, ethical views, and cognitive strategies and limitation rather than trying to determine their "true" individual welfare function, when discussing policy recommendations (Johanssons-Stenman 2002).

- The well-known phenomenon of the disparity between willingness to pay and willingness to accept, that arises in experimental and survey settings (Hanemann 1991, Horowitz and McConnell 2003).

In this brief overview of some economic concepts of the theory of choice, those issues are highlighted, which the present System Dynamics study tackles, too. The observed waste separation behavior of households, measured in fraction separated, is described as a choice between participating in separating or not. Therefore, personal preferences are operationalized by *acceptable separating time*, and *acceptable separation cost* that may be seen similar to the approach of the concept of willingness to pay.

However, there are some major differences in the overall choice concept of the SD-SWM-model. Firstly the preferences can be influenced by a social norm for separating behavior. Secondly, the observed separation pattern is not described by a utility function that will be maximized, but rather by simple deliberation processes comparing acceptable costs

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[29] This empirical approach is referred to as the method of stated / revealed preferences or as contingent valuation method. A comprehensive discussion of the stated preference method or contingent valuation method is given in Becker (1993) - http://www.ecosystemvaluation.org/contingent_valuation.htm#over.

and real costs in separating but also by comparing real cost and alternative action costs of not separating. Further, the SD-SWM-model choice approach conceptualizes mainly two groups of people with different preference structures – those that may develop intention to separate and those that may not. Finally, the model structure also includes measures of the influence of habits that are actually not part of a choice process.

These concepts can be seen as a first attempt to deal with the preference-choice-issues that are often raised in the economic discussions, in a System Dynamics approach. Therefore, this specific SD-choice structure may be seen as an important building block of the overall SD-SWM-model including crucial psychological concepts explaining behavior. This would be an important precondition for an adequate policy analysis instrument trying both to exclude systematic biases and to identify important intervention points also considering changes in personal factors.

3.3.2   Reaching a social optimum of solid waste management

The preceding literature chapter mainly focused on concepts and theories of different disciplines explaining individual behavior and choice and specified the aimed-for perspective on the micro-process as a means to explain the system behavior in the particular area of solid waste management.

In this chapter we will set forth the environmental economic perspective on solid waste management. In this view the objective of solid waste management is to pursue an environmental policy in which marginal (environmental service) costs equal marginal benefits. Following Oates (1999), economics can give three basic messages for environmental protection:

- It gives reasons why market failure and externalities make public intervention necessary: the absence of an appropriate price for certain scarce resources (in our case primary resources), for externalities (e.g. pollution from waste disposal), and for social goods (like "waste" collecting services).

- It provides guidance for the setting of standards for environmental quality: as long as the marginal benefits from a service are higher than the marginal costs (often called marginal abatement costs) it is worthwhile to provide additional service units.

- It offers some insights about the design of policy instruments to achieve desired environmental standards in the most effective and efficient ways. The leading message for a good policy intervention is to minimize the abatement costs in the short run and to provide incentives over the longer term for polluters to discover and introduce better techniques for controlling polluting waste emissions[30].

For the purpose of this work the last point is crucial, since economic policy-instruments are an important pillar of the Swiss solid waste management strategy. In order to get a better

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[30] For a broad overview of on economic perspective on environmental and resource management see Oates (1999), for deeper insights see Oates (1992).

understanding of the reasoning for these strategies some economic studies examining different policies for solid waste management will be presented.

Ayres and Kneese (1969) pointed out that externalities associated with disposal of residuals resulting from the consumption and production process is an important class of externalities.

> *"Their economic significance tends to increase as economic development proceeds, and the ability of the ambient environment to receive and assimilate them is an important natural resource of increasing value" (282).*

Furthermore, these authors emphasize that isolated and ad hoc taxes and other restrictions are important but not sufficient for an optimal control of natural resources. What is needed is a more systematic and coherent program of environmental quality management including public investment programs. While Ayres and Kneese (1969) pointed out the impracticality of reaching a pareto-optimal solution by applying economic instruments early on, recent economists are in search of second-best solutions for solid waste management[31].

Both households and firms can make costly waste reduction efforts. Firms' behavior influence the intrinsic waste content and households' behavior affect the amount of waste to be disposed of. Based on empirical economic studies Choe and Fraser (1999) conclude that

> *"without explicit incentives, neither the firm nor the household will necessarily undertake costly action to reduce the amount of waste, but explicit incentives such as waste charges might induce households to choose the option to illegal disposal" (235).*

While some studies focus either on source reduction in the production stage (e.g. (Palmer, Sigman et al. 1997; Palmer and Walls 1997) or on the waste diversion in the consumption and disposal stages (e.g. Dinan 1993), others offer a comprehensive framework analyzing policy instruments that are directed at production, consumption, and disposal stage (e.g. Fullerton and Wu 1998, Choe and Fraser 1999, Shinkuma 2003).

The model from Fullerton and Wu (1998) illustrates that optimal waste management policies depend crucially on households' waste separation behavior including illegal dumping. Policies such as various combinations of environmental taxes on the firm and waste collection charges only lead to the first best optimum if household waste separation behavior is not significant. A waste collection charge gives incentives for both high separation efforts and illegal dumping thus rendering a Pigouvian tax sub-optimal (Fullerton and Kinnaman 1995; Fullerton and Kinnaman 1996). The authors suggest a combination of policies such as a waste collection charge on the household, explicit monitoring of illegal

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[31] For a comprehensive discussion of the first best- and second best solution and of problems with Pigouvian tax see (Weimann 1991): In the first best solution an environmental tax internalizes the externalities in such a way that the marginal emissions-cost equals the marginal prevention-cost (Pigouvian tax) determining the pareto optimal amount of emissions. When information problems about marginal prevention- and emission-costs render a pareto optimum impossible, the second best solution aims to find a tax that leads to an exogenously determined emission standard in a cost minimal way.

waste disposal and an environmental tax on the firm. Choe and Fraser (1999) further emphasize the role of monitoring costs and the willingness to comply with environmental regulations for an optimal solution. Based on their comprehensive equilibrium model including both firms' and households' behavior the authors conclude that whether it is optimal to eliminate any illegal waste disposal entirely depends on the monitoring costs necessary to induce such extreme compliance. Furthermore, they emphasize the interdependent nature of policy instruments at different levels of implementation. "Such an interdependence calls for careful coordination of policies among different regulatory bodies" (243).

Shinkuma (2003) suggests a further economic model and shows that the magnitude of transaction costs associated with recycling subsidies and the price of the recycling good the firm has to pay to the household are relevant to the choice of second best policies.

The following Table 3.7 summarizes his findings.

	Firm has to pay for getting the recycled good from the household (positive price for recycled good)	Firm gets paid for taking back the recycled good from the household (negative price for recycled good)
High transaction costs for recycling subsidies to households	Unit pricing and advance disposal fee	Producer take-back requirement system
Low transaction costs for recycling subsidies to households	Deposit – refund system	Deposit – refund system

Table 3.7: Second best policies (adopted from Shinkuma 2003): The advance disposal fee is interpreted as an environmental tax on the firm and unit pricing would correspond to a charge per bag waste.

These recently published examples of economic approaches analyzing solid waste management policies show that theoretically the social optimum could be reached by different regulatory policies and that they are equivalent substitutes. However, in the real economy certain factors prevent such an optimum. Shinkuma (2003) interprets this observation as follows: "The policy direction to follow has its most relevance as an empirical rather than a theoretical question" (79).

3.3.3 Conclusions on the Economic- and the System Dynamics- approach

Although economics may help give theoretical arguments about why a nation wide policy of solid waste management could be a cost efficient way of internalizing externalities and seeking a social optimum in a perfect world, with perfect markets and perfect decision-makers, the System Dynamics model approach may help understand complex phenomena of the imperfect and "faulty" reality. Hence, the SD-SWM-model offers a complementary theory explaining the observed phenomena.

In this sense, the specific SD-SWM-model may help practically in micro controlling and in fine-tuning the systems performance, whereas the economic approach may help find policy principles that would theoretically lead to an "optimal" solution. Furthermore, economics describes an "optimal solution" and the state of the system in equilibrium whereas the System Dynamics model focuses on the transition process. In having this focus it helps to understand the driving forces leading the system from one to another equilibrium.

One strength of economics is its consistent mathematical formalization of the theory. Therefore, the theory can guide the problem structuring process leading to an inter-subjective explanation and solution that is well understood between economists and can easily be replicated. However, this may also limit its adequacy for certain issues (see Thaler 2000, Tversky and Kahneman 1974, Kahneman, Knetsch et al. 1986)) and may be seen as over simplistic (Forrester 2003, Radzicki 2003, Atkinson 2003, Shilling 2003).

Contrarily, the System Dynamics modeling approach aims at developing a useful mathematical model addressing a specific issue and offering a dynamic theory for "the family of systems to which the specific one belongs" (Forrester 2003:4), including generic structure components that could be building blocks for other applications. Furthermore, the model-conceptualization and theory-building process is more open and can draw from the knowledge from different sources such as from different scientific disciplines but also from the mental models of the actors that have to deal with the specific situation. Subsequently, the perspective on a problem may be more encompassing and specific – and may also offer different insights and policy implications than pure economic perspectives (see Andersen 1980). Of course this approach will also have its drawbacks. Those will be discussed more explicitly later on in Chapter 6.4.2 (Strength and limitations). A more comprehensive explanation of the System Dynamics approach is given in Chapter 4.1.2 (System Dynamics and Group Model Building).

3.4   System Dynamics models for solid waste management

In the literature only few System Dynamics models exist for solid waste management that focus on individual solid waste behavior, market forces, and public policies. In this section some of this relevant work and sophisticated System Dynamics models for solid waste management will be described; those developed by Randers and Meadows (1973), Mashayekhi (1988), Chung (1992), and Wäger and Hilty (2002).

The model suggested by Randers and Meadows (1973) focuses on the causal links that determine the behavior of natural resources - solid waste system in general and for copper specifically. In the model long-term relationships affecting an industry, its sources of raw / recycled material, products in use (as an indicator of the material standard of living), and the stock of solid waste are emphasized. Subsequently, the model perspective is neither on the competition among individual firms nor on the behavior of individual consumers. However, this model addresses research questions that are related to those of the present study, since it tackles with issues of resistance to change in a system but from a macro-perspective, e.g.:

- "How does one go about collecting and sorting billions of tons of waste?" (173).

- How to change the behavior of the various actors involved?

    "The enormous investment in present-day technology based on the present consumption patterns is the basis of a significant resistance to change. So is the habit of the consumer to purchase anything he wants – regardless of whether it is feasible for disposal or recycling – and throw it away afterward, more or less wherever he pleases, and at no cost" (174).

The various policy-experiments highlighted some important intervention points and their effectiveness but also illustrated some policy compensating effects: (e.g. restoring forces compensating a 50% tax on extraction of natural resources). The main insight is that the system behavior can only be improved in the desired direction by applying policies at different points in the system at once; such as a tax on extraction, a subsidy to recycling, an increase in the product lifetime, a doubling of the maximum recycling fraction as well as a reduction of raw material per product, provided that the product lifetime is not suffering. A further important insight is that the implementation of these policies should not be postponed till the material standard of living starts to decrease due to scarcity in natural resources, since then those policies will fail to have a significant effect.

The model from Mashayekhi (1993) represents a different focus on solid waste management. The purpose of this model is to understand the costly transition from a landfill-dominated mode of disposal to alternatives such as incineration and recycling in the New York State solid waste system. It evaluates costs of financing alternatives and capacity development questions. Mainly the influence of different financing strategies for capacity building for recycling, incineration and dumping were analyzed considering different cost shares between state and localities and different tempi of revenue generation. The comparative policy analysis showed that those strategies with no state financial aid resulted in the highest overall system costs due to a dramatic increase in illegal dumping:

    "An interesting sort of two-player game (in the game theory of that word) emerges. If state and local governments work together, the overall best performance emerges – a classic win-win situation. However, if one player moves to assume costs and the other does not, then a strict cost serve, the player who moves first becomes a cost loser and the other player a cost winner" (Mashayekhi 1988:*41).*

The rich structure of the model including eight sectors (solid waste generation sector, landfill sector, incineration sector, recycling sector, environment sector, regulation setting sector, solid waste allocation between the different alternatives, as well as budget planning, acquisition and allocation, and a state government sector) allows to track important financial quantities such as the tax rates for solid waste budget, the fraction of the total costs being financed by user fee, or the overall debt being accumulated to finance the solid waste system.

Chung's (1992) SD-SWM-model investigates a further relevant issue. Chung developed the model in order to analyze how information paths in a multi-stage production/distribution structure affect the performance of public policies promoting waste

recycling markets. The model includes four sectors: a source separation, a primary recovery, a waste recycling, and a final demand sector. The model served as a laboratory in order to test two typical market development policies (an increase in the average waste disposal cost, and an increase in the primary raw material price) given different information environments. The findings of the policy-experiments suggest two information policies improving the overall performance of the two market-development policies. An information policy (offering timely and accurate information) aimed to control the capacity development process in the recovery and in the recycling sector and an information policy providing a centralized data bank that gathers and distributes market information across individual sectors. The simulation results illustrate that the implemented information policies reduced the amplitude of market instability and resulted in a better capacity utilization increasing the efficiency. Those results emphasize the influence of information networks embedded in the multi-stage structure of waste recycling markets and give evidence on the role of the government as an important information-coordinator.

All three introduced SD-waste models deal with minimizing transition costs from a "throw-away society" towards "zero waste society" analyzing different policy interventions from a macro-perspective. Rander's and Meadows' model can best be compared with a natural-resource-management model including aspects of inter-temporal allocation of natural resources. Mashayekhi's model takes on the perspective of a benevolent dictator and serves as a capacity-planning and financing model. Finally, Chung's model analyzes the role of information policies.

A more specific question is addressed in the SD-model suggested by Wäger and Hilty (2002).

"What will happen, if up to 200'000 tons of plastic waste per year are taken out of the waste stream, which is incinerated in Swiss MSWI[32] plants, and fed into thermal recovery or mechanical recycling instead?" (Wäger and Hilty 2002: 177).

In order to evaluate the ecological impact of this strategy the System Dynamics modeling approach is combined with the expertise from the field of Life Cycle Assessment. The simulation run indicates that separating industrial plastics waste has economic and ecological advantages under the assumption of existing market for secondary plastics material. This model is an example of a more disaggregated decision support system (DSS) with a sophisticated environmental module. However, it does not address any compliance issues.

The present SD-SWM-model provides a complementary "micro-structure" addressing compliance issues that were not taken into account by the others. Only Chung's model includes a simple decision function determining the source separation rate at the local level including variables of "opportunity costs for source separation", and "demand/supply ratio" as well as "inconvenience". Those variables would offer interesting interfaces between Chung's and the present models.

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[32] MSWI: Municipal Solid Waste Incineration

3.5   Local government

This chapter highlights the role of the local government in offering public goods and services such as the provision of a waste-collecting system. This issue is theoretically discussed in the decentralization debate. In the pertinent literature there is a large debate about decentralization either emphasizing the shift of responsibilities downwards from national, respectively central, and federal levels to state and local levels or shifting responsibilities from the public to the market sector, i.e. increase decentralization to market forces (e.g. Bennett 1990). Traditionally collective goods have been seen as public goods[33]. But recent studies show that local governments use both private and public sector mechanisms for providing collective services (e.g. Warner and Hebdon 2001). Following R. Musgrave's tripartite division of the public sector the primary rationale of decentralization is the provision of public goods and services[34]: It is at this level where the services offered can best be adapted to the local circumstances and to the needs of the individual agents. The provision of public goods at the local level would have similar function as a private market mechanism, since individuals would have a choice by "voting a pied"[35] (Tiebout 1956). Individuals would choose to live in that municipality providing their preferred public services in the desired quantity and quality. As these basic theories recognize simple "market"-concepts in the public sector, recent research shows how local governments become key players in creating and structuring private markets for public goods. Based on research findings Warner and Hebdon (2001) concludes:

> *"In many local and regional contexts, government may be the only player. Markets are not given; they are created. Especially in public services, markets must be created with care and attention to equity, service quality, and competitive prices. ... Futures studies of restructuring must give more attention to the role of local government as service provider, regulator, and market player" (333).*

In his work[36] he could show that local government seeks efficiency goals with public values and attends to the competitiveness of both public and private markets for governments services. These lines of research stress the role of local governments as an important key player in market creation. For environmentally relevant services such as provided in solid waste management strategies this may be highly relevant, for both aiming to foster competitive recycling markets and inducing more environmentally sound lifestyles including consumption respectively disposal patterns of citizens.

Although those arguments emphasize the importance of local governments for environmental policy there are other arguments for a more central environmental policy in

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[33] The term collective goods is used for goods that are neither excludable nor rival, whereas the term public good refers to a good that is provided by the public sector. However, in the literature often public goods are defined similarly to collective goods (e.g. Mankiw 1998:221).

[34] Musgrave (1981; 1983) suggests a tripartite division of the public sector, in which he discusses the allocation of functions: Macroeconomic stabilization and income distribution incumbent on the central government, allocation of collective goods assigned to the local government (for an overview see Oates 1990).

[35] Voting with their feet

[36] Warner and Hebdon (2001) bases his conclusion an a survey of chief elected township and county officials in New York and different logistic regressions models, conducted in 1997.

order to both realize economies of scale and avoid spillovers or externalities (Feser and Hauff 1996). Therefore, an effective and efficient environmental policy strategy such as a national solid waste strategy mostly includes all governmental levels. Feser and Hauff (1996) distinguish three main clusters of environmentally sensitive tasks that are assigned to the local level: Monitoring and averting of danger, and administration and implementation as well as environmental planning and precaution. Furthermore, they also stress functional government failure (Staatsversagen) as a source of policy failure (Politikversagen) and refer to lack of understanding of complex problem-structures. Concerning environmental issues, the authorities' willingness to conform to voter preferences would exist but their measures lack efficiency. In view of the complexity of environmental issues, the difficulty to anticipate the consequences of interventions in economically and ecologically dynamic complex systems, functional government failure may be a crucial reason of policy resistance.

> *"Bezogen auf die kommunale Umweltpolitik bedeutet dies, dass die politische Bereitschaft, sich entsprechend dem Wählerwillen zu verhalten, zwar vorhanden ist, es den durchgeführten Massnahmen aber an ökologischer Effektivität mangelt. Angesichts der Komplexität der meisten umweltpolitischen Probleme und der Schwierigkeit, die Reaktion innerhalb ökonomischer wie ökologischer Regelkreise auf regulierende Eingriffe zu prognostizieren, dürfte funktionelles Staatsversagen eine nicht unbedeutende Ursache umweltpolitischer Misserfolge sein"* (14).

This short overview of the role and challenges of local governments shows the relevance of their expertise, entrepreneurship and overall understanding of complex problem situations. Hence, better-informed decisions may be crucial for an effective and efficient environmental policy in general and for solid waste management in specific. Providing them with problem focused decision support tools could help mitigate functional government failure.

3.6   Policy design, strategies and instruments

In the preceding sections components for an improved *system understanding* were described. Environmentally relevant behavior was analyzed from a micro-perspective in order to understand macro behavior and to derive some policy conclusions. Furthermore, the role of local governments in environmental policy was discussed. In the next sections some light will be shed on strategies, instruments and policy design in order to clarify intervention possibilities at the local level. Hence, the focus will be on *transformation-knowledge*.

3.6.1 Solid waste management and strategies for a sustainable development

In environmental policy efficiency and sufficiency strategies are often discussed. Whereas efficiency strategies aim to reduce the consumption of natural resources and environmental pollution by technological progress, sufficiency strategies aim to reduce the propensity of environmental consumption by changes in lifestyles. Recycling strategies may have both components, considering the separation behavior of citizens. However, those strategies

should be complemented by alignment strategies of the various stakeholder interests (Hofmeister 1999). Furthermore, Dullin (1999) emphasizes the consistency-principle referring to an adjustment of the material flow to the regeneration capacity of nature. However, he criticizes that in a recycling management perspective the energy and material flow would not take into account the capacity of natural metabolism processes.

In order to implement those guiding principles in citizens' daily life deliberations, concrete action alternatives and their consequences should be perceivable. According to Dullin (1999) daily life issues such as separation behavior, health and safety considerations would offer important interfaces that could be used in communication strategies for environmentally sound products and action alternatives. Bruppacher (2001a) found in her study, that in self-modification strategies of households those goal alignment strategies are also often used.

3.6.2 Types of instruments

One aim of this work is to develop a decision support tool that explains the interactions in the system when trying to take initiatives to implement environmental policy strategies such as those discussed above. However, it is not only crucial to understand these processes but also both to identify important variables determining the success or failure of such initiatives and to know how those variables could be influenced. Therefore, more concrete knowledge about the mode of function of policy instruments is required.

Kaufmann-Hayoz, Bättig et al. (2001d), (an interdisciplinary team of researchers) suggest a typology of policy instruments that builds on traditional policy types such as command and control instruments and economic instruments but elaborates on further types such as service and infrastructure instruments, collaborative agreements, as well as communication and diffusion instruments. This typology aims to point out the mode of function of policy instruments. Therefore, it is seen as especially suitable to complement a System Dynamics policy analysis approach in offering the right information about which instrument or mix of instruments (policy-package) to use in order to activate the identified intervention points, or to influence crucial variables in the desired direction.

A comprehensive description of the typology is given in Kaufmann-Hayoz, Bättig et al. (2001d) *"A Typology of Tools for Building Sustainable Strategies"*. At this point, a short overview of these types of instruments is given, focusing on the mode of function at the micro-processes.

- *Command and control instruments:* They restrict the scope of action and are binding for the target group.

- *Economic instruments:* They offer economic incentives and may influence choice deliberations towards a favored action alternative. Often it is hard to predict the impact and effectiveness since its influence on the target group depends on people's preferences.

- *Service and infrastructure instruments:* The mode of function of this type is based on two principles. Firstly, services and infrastructure can determine what is objectively possible or what is not possible to do and how convenient it is. Secondly, in a choice situation the more convenient alternative will be considered.

- *Collaborative agreements:* They can be legally binding or non-binding commitments and may be effective since people tend to stick to engagements and commitments. Collaborative agreements may be promising when goal alignments can be found. However, the scope of impact is confined to the contractual partners.

- *Communication and diffusion instruments:* They stimulate the thinking of individuals and may shape societal discourses hence modifying motivational, cognitive and social preconditions of actions. They can induce changes in preferences. However, the power of communication instruments must be transported to large groups by diffusion instruments in order to reach a societal impact. Furthermore, they may unfold a long-term impact if latent trends and social norms can be activated or revealed.

Table 3.8 lists the instruments assigned to the different types hence specifying the understanding of the different types.

COMMAND AND CONTROL INSTRUMENTS	ECONOMIC INSTRUMENTS	SERVICE AND INFRASTRUCTURE INSTRUMENTS	COLLABORATIVE AGREEMENTS	COMMUNICATION AND DIFFUSION INSTRUMENTS
Environmental quality standards (impact thresholds and standards) **Emission standards** • best available technology • prescriptive technology standard **Product standards and regulations for the use of pollutant substances** • restriction, rationing, or prohibition • product standards **Licensing** • licence to construct • licence to operate • licence to sell **Liability regulations**[1] • strict liability • reversal of the burden of proof • compulsory third party liability insurance **Zoning** • land use regulations • water protection areas • nature conservation zones	**Subsidies** • grants • tax allowances • soft loans • guarantees • compensation for foregoing use of the resource **Incentive taxes** • taxes on energy/resources • taxes on emissions • taxes on products/processes **Charges** • one-time charge for connection to services • recurrent charges for use • charges on advantages (value-added tax) • pre-paid disposal fees **Deposit-refund-systems** **Market creation** • tradable allowances or permits • joint implementation **Incentives as parts of action campaigns**[2] • rewards • lotteries • contests/benchmarking • discounts	**Service instruments** • offering or improving ecologically sound products • withdrawing environmentally undesirable products • offering or improving services that allow or facilitate ecologically sound action • reducing services that allow or facilitate environmentally undesirable action **Infrastructure instruments** • offering or improving infrastructure that allows or facilitates ecologically sound action • dismantling or degrading infrastructure that hinders or inhibits ecologically sound action	**Public-private agreements** • agreements on prepaid disposal fees on specific product groups • agreements on consumption goals or standards • formal agreements with individual companies **Certifications and labels** • with legal compliance • without legal compliance	**Communication instruments without a direct request** • presenting facts • presenting options • presenting appraisals, goals, and norms • providing experience of reality • presenting model behaviour • giving feedback and enabling self-feedback **Communication instruments with direct request** • persuading about facts • persuading about options • persuading about appraisals, goals, and norms • sending appeals • presenting prompts and reminders • stimulating self-commitment **Diffusion instruments** • establishing direct personal contact • establishing contact via person-to-person media • establishing contact via mass media

[1]   Liability regulations are often classified as economic instruments.

[2]   These instruments – although not usually described as economic instruments – are placed here, because from the target group's perspective their rationale is the same as in the other economic instruments (see text for further explanations).

Table 3.8: A typology of policy instruments for a sustainable development (adopted from R. Kaufmann-Hayoz et al. 2001: 40ff).

3.6.3   Designing packages of environmental policy instruments

As described above different types of instruments have different modes of function, and specific weaknesses and strengths. With each instrument only parts of action guiding conditions (situational or personal ones) can be influenced. In order to reach a high or a robust initiative compliance a combination of environmental policy instruments may be required. One aim of this work is to find out which combination of instruments may be promising in the specific case setting. Although it is assumed that no generic optimal policy mix exists, case specific policy-packages leading to a robust policy outcome are sought.

However, there is a dearth of literature on the effective mixes of instruments. Rutkowsky (1997) suggests a distinction between a historical development of mixes of policy instruments, and a combination of instruments in transition phases, as well as between long-term implementation of policy-packages. Based on research findings Kaufmann-Hayoz (2000) and Kaufmann-Hayoz, Ulli-Beer et al. (2001c) suggest some *guiding principles for designing policy-packages* and articulates some interaction hypotheses.

- Complementary instruments should be implemented aiming to increase their mutual effectiveness such as combining regulations, economic subventions and timely information adjusted to the target group and demonstrating model behavior. Communication and diffusion instruments could increase the acceptance of regulatory and economic instruments, whereas subventions and regulations could help turn environmentally friendly concerns and knowledge into actions.

- The different instruments should send out a congruent appeal.

- The static effect of command and control instruments could be compensated by policy-packages offering further incentives for a dynamic improvement process. Such a policy-package could include economic instruments, communications and diffusions instruments, as well as service and infrastructure instruments.

- Collaborative agreements are best implemented in clearly declared environmental strategies in order to avoid regulatory enforcement activities.

3.6.4   Why do citizens comply with environmental regulations and informal rules of conduct?

Up to now we have seen that many different types of tools exist that could help "steer" citizens' behavior in the desired directions and to reach environmental goals. In order to design effective policy-packages it may be useful to know why citizens would comply with environmental policy or regulation.

Cohen (1998) gives a comprehensive overview of the variety of theories in economics, sociology and public policy literature that try to explain policy compliance of individuals and firms (e.g. theories of firm behavior) on the one hand and enforcement behavior of agencies (e.g. bureaucratic behavior theory, maximizing environmental benefits of enforcement) on the other. They are mainly based on the rationale of "utility maximizing" and on

"maximizing" social welfare describing compliance decisions or optimal enforcement policies resulting in an optimal deterrence policy (e.g. Becker 1968). However, there are also theories explaining compliance decisions that integrate in their framework moral considerations such as social norms (i.e. it is the right thing to do) and capacity (i.e. having the knowledge of the rules and technologies) in their framework (e.g. Bardach and Kagan 1982, and Burby and Paterson 1993).

However, in order to design policy-packages leading intrinsically to high compliance (i.e. without an explicit deterrence policy) it is important to understand the factors that shape compliance with (environmental policy) regulations. The preceding literature review in this book pointed out that different situational and personal factors influence motivations and behavior. A compliance study (Winter and May 2001) that is in line with this "driving factors" approach gives evidence that compliance can partly be explained by the following factors: Calculated (benefits-and-cost deliberations), normative (moral duty and agreement with the importance of the regulation) and social motivations (earning approval and respect of significant others); the capacity to comply, and the awareness of rules. Furthermore, they could demonstrate strong interactive effects: interaction of duty to comply and awareness of rules, interaction of enforcement style and awareness of rules, and interaction of capacity and awareness of rules.

These findings are in line with the theoretical consideration made by Flury-Kleuber and Gutscher (2001). They emphasize that policy-intervention has to be in line with individuals' motivations in order to increase the compliance-efficiency of policies. "The better an instrument fits the motivational preferences of the target persons, the more efficient it will be" (125). These considerations stress the importance of factors that influence compliance when policy-packages are designed. Different types of instruments would also serve different motivations. Furthermore, a policy analysis model should also include those factors explaining compliance or non-compliance with environmental regulations or with informal rules of conduct. Subsequently, processes leading to policy resistance can be identified and "corrected".

3.7   A synthesis of human behavior and policy

The preceding sections gave an overview of current research and issues on the topic of environmentally relevant behavior and public policy. They demonstrated the variety of perspectives and factors that could be taken into account in order to tackle observed phenomena of solid waste management at the local level. But it also showed important reference theories that would offer complementary insights.

Since this research approach does not adopt one specific disciplinary lens explaining the observed real world problem but a kind of "driving forces" or "main factor approach" it may be useful to have a simple theoretical framework. This should incorporate more than one disciplinary perspective and would serve the purpose of a substitute for a disciplinary focus and also the purpose of a heuristic guiding and structuring the model development process.

Such a theoretical framework was developed by the authors Kaufmann-Hayoz, Bättig et al. (2001) and described by Kaufmann-Hayoz and Gutscher (2001a). It is a first synthesis of findings that emerged from the intensive research about human behavior and environmental policy instruments in the SPPE and offers a *"Feedback Perspective On Human Behavior And Public Policy"*. The basic assumptions underlying this framework are presented in Figure 3.4 and described below.

Figure 3.4 represents the basic assumptions about human action as a result of an interaction between the internal structure of the actor (personal factors and processes) and the external structure (contextual factors and processes; cultural, socio-economic, institutional, and physical framework). The external structures offer options but they also constrain human behavior. They are the result of a multistage decision process in political/administrative, technological and economic domains.

"All actors have only limited possibilities to alter their own framework of actions, because they are determined by other actors' decisions. However, collective actions or social practices stabilize and reproduce the mutual framework conditions, or, alternatively, they contribute to their change. Over time there is a 'co-evolution' of individual and collective patterns of behavior and its framework" (Kaufmann-Hayoz and Gutscher 2001a:24).

This feedback view is in line with the control theory proposed in Powers' major work, 'Behavior: The Control of Perception' (Powers 1973, see also Powers 1990). He emphasizes that individuals not only behave as they do because of the stimuli they perceive but also that how individuals behave affects what they perceive. Furthermore, some similarities to Giddens' structuration theory (e.g. see Giddens 1984) can be seen. The present framework not only incorporates this social feedback view explaining the constitution of a society but it also emphasizes further resources and constraints guiding behavior and structuring a society such as physical and economic ones. In addition it is also in line with recent theoretical approaches explaining environmentally relevant behavior (e.g. Stern, Dietz et al. 1995; Stern 1999; Stern, Dietz et al. 1999; Stern 2000, Dietz and Stern 1995; Dietz, Stern et al. 1998, Foppa and Frey 1990).
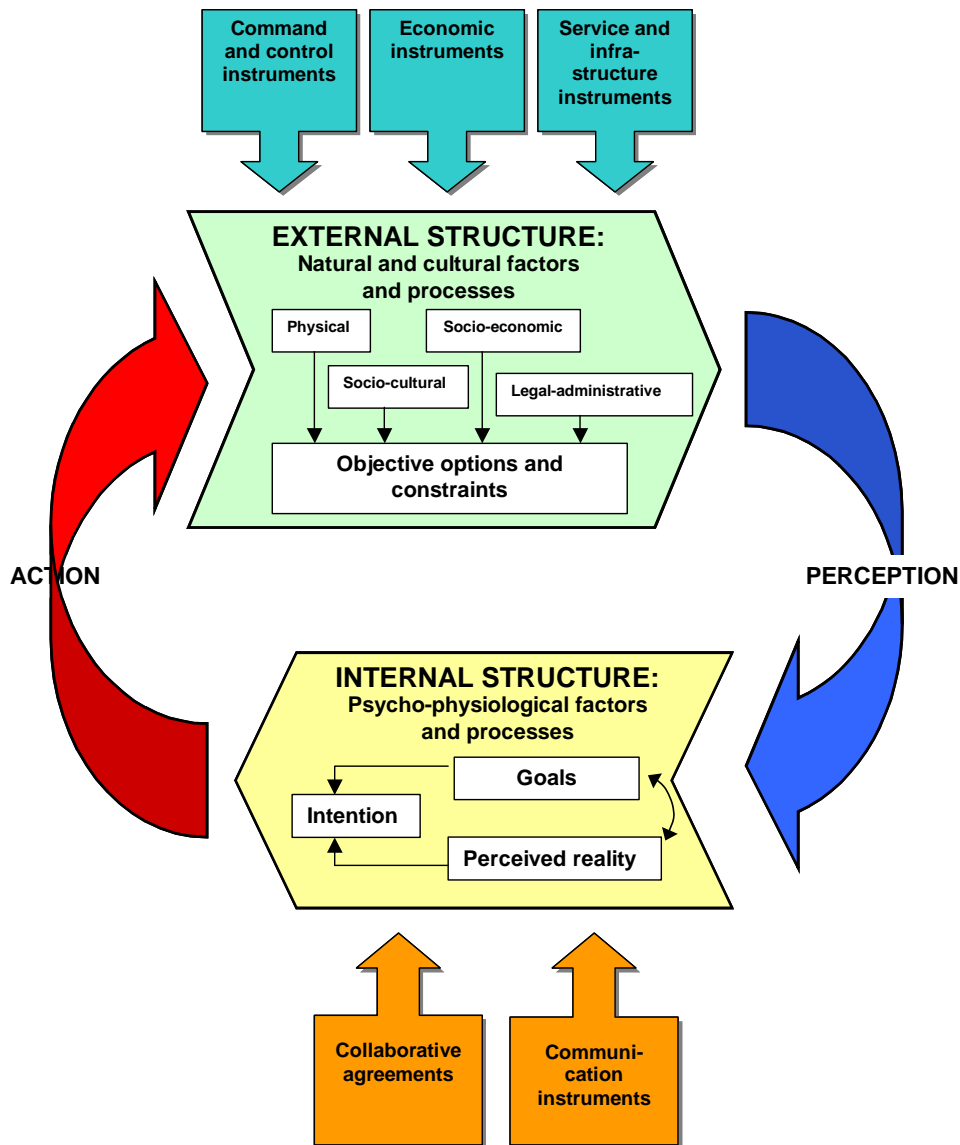
Figure 3.4: A Feedback Perspective on Human Behavior and Public Policy (adopted from Kaufmann-Hayoz et al. 2001:82)

Based on the feedback framework, Kaufmann-Hayoz et al. (2001) conclude that policy makers can alter either the internal or the external structure in order to induce behavior change. Different types of policy instruments such as *"command and control instruments"*, *"economic instruments"*, *"service and infrastructure instruments"* and *"collaborative agreements"* can alter the external structure. Policy types such as *"communication and diffusion instruments"* and also *"collaborative agreements"* can modify the individual's internal structure.

In the present study this framework will be used as a heuristic that helps conceptualize and build a System Dynamics SD-SWM-model focusing on the interactions of contextual and personal factors and possible intervention points.

4 Methodology and research design

So far, the different fields of research and main insights from different disciplines on environmentally relevant behavior and environmental policy were presented. It was highlighted that this study draws on existing theoretical concepts in order to gain complementary insights about dynamics and interactions explaining environmental management issues. In the following section, some basic aspects of the applied methods are discussed and the research process is described in order to provide the reader with a better understanding of how to position and evaluate this study.

4.1 Aspects and overview of the applied methods

4.1.1 The study and its relation to leading research paradigms

The paradigms underlying the present study will be discussed to facilitate the assessment of its contribution. The evaluation of scientific findings is based on prevailing standards in the specific research paradigm. According to the incommensurability-thesis (Kuhn 1962) the validity of scientific findings and theories depends on their paradigms, hence theories of different schools cannot be compared since – they are incommensurable. In the following section, characteristics of the research approach will be discussed based on main issues of philosophy of science and of theories of society in order to reveal its relevant school of thought.

Philosophy of science and theory of society

An often-used framework to reveal the underlying philosophy of social research approaches was suggested by Burrell and Morgan (1979). It contains two axes that illustrate two distinct dimensions: the *philosophy of science* (subjective versus objective views) and the *theory of society* (sociological regulation versus radical change)[37].

The four aspects of the philosophy of science, ontology, epistemology, human nature and methodology characterize the two opposite positions of subjectivism and objectivism (see Table 4.1).

Subjective views	Aspects of philosophy of science	Objective views
Nominalism	Ontology	Realism
Subjectivism	Epistemology	Positivism
Voluntarism	Human nature	Determinism
Ideographic	Methodology	Nomothetic

Table 4.1: The main dimensions and aspects of philosophy of science (adopted from Burrell and Morgan 1979).

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[37] For a comprehensive discussion of the Burrell-Morgan framework see Kieser (1999).

The two opposite positions about the nature of society distinguish research approaches interested either in the regulation of the status quo or in understanding societal conflicts. The main issues of both positions are portrayed in Table 4.2.

„Regulation"	„Radical change"
-Regulation of the Status quo	-Inspiration of radical change
-Describing social integration, cohesion and order	-Describing structural contradictions
-Describing processes of needs satisfaction	-Describing deprivations and exploitation (psychic and material)
-Creation of consensus	-Articulation of modes of domination and sources of power
-Solidarity with fellow society members	-Emancipation from „prison" society
-Explaining actuality	-Envisioning potential and facilitating emancipation

Table 4.2: Main issues of the two opposite positions about the nature of society (adopted from Burrell and Morgan 1979).

The two axes determine the four quadrants each specifying a separate paradigm, to which social theories could be assigned (functionalist sociology, interpretative sociology, radical structuralism and radical humanism). However, the following discussion shows that it is not possible to clearly assign the present research to one of the quadrants.

First, in reference to *ontological assumptions* the focus on personal structures is in line with the nominalist position – the missing precondition for environmentally responsible behavior would be a product of cognitive and mental processes whereas considering contextual constraints would be in line with the realist view, in which the social world existence is assumed as independent from individual humans and their appreciation.

Second, in reference to *epistemological assumptions* both types of knowledge are made accessible for this work. The preliminary study draws also on subjective knowledge – on the mental models of the concerned actors, whereas in the main study inter-subjectively condensed causal laws, and theoretical concepts as well as objective findings are integrated in the model. The hypothesized objective structures of the real world are reproduced in the model. The hypothesized relationships can be falsified and refined.

Third, the underlying *human nature assumptions* of the study encompass both positions:

- Deterministic assumptions when referring to both the gap between environmental concerns and action and to the working hypothesis: *If essential preconditions for environmentally responsible behavior are missing then only few citizens will develop environmentally sound behavior patterns.*

- Voluntaristic assumptions when referring to deliberation processes and the design of public policy aiming to create a desired "action"-environment.

Finally, even in terms of *methodology* both seemingly diametric positions could be found in the approach: ideographic assumptions in the preliminary study aiming to access individuals' problem interpretation as well as nomothetic assumptions when identifying and integrating relevant theoretical concepts in the model.

In addition to the ambiguities discovered in the subjectivism – objectivism debate, similar problems arise when trying to evaluate the assumption of *nature of the society*. While the broader sustainable development topic could be seen as a soft revolution including main issues of the "radical change" paradigm, the problem-oriented focus on solid waste management is clearly in line with regulation-issues.

The insights of this brief discussion suggest that the present work cannot be assigned to one of the traditional paradigms mentioned above (functionalist sociology, interpretative sociology, radical structuralism or radical humanism). The difficulty associated with assigning the present research to one of the four traditional paradigms is related to the fact that the System Dynamics paradigms is itself the subject of an ongoing debate in the literature. Lane (2001a, 2001b) concludes that it is difficult to assign System Dynamics unequivocally to one traditional paradigm. But he also offers a resolution to these problems and suggests that "System Dynamics relates best to the theories that seek to integrate those views based on the action of individual human agents with those views that emphasize structural influence" (306) referring to Giddens' structuration theory (e.g. Giddens, 1984) and other integrative theories. He argues that contemporary social theories "have the potential to generate a string of exciting and innovative modeling tasks, tasks that will allow researchers to display the sort of empirically grounded and practically minded approach that is the strong heart of System Dynamics" (306).

Whereas Lane's considerations give evidence that System Dynamics is a good match with agent-structure frameworks, Schwaninger (1997, 2002), and Weber and Schwaninger (2002) suggest that System Dynamics is at the core of Integrative Systems Methodology (ISM). The authors illustrate how apparently contradictory propositions that seem incommensurable could be overcome both by combining qualitative and quantitative SD modeling and by building a bridge between System Dynamics and complementary methods such as Organizational Cybernetics. At the heart of ISM is the polarities framework (see Figure 4.1) that illustrated how ISM may help overcome paradigm-paradoxes. "Dissolving these paradoxes can now be based on combining the opposites in all four dimensions, by means of the methodology proposed here. In fact, it turns out at a more profound level of observation that the apparent opposites are complementary" (Schwaninger 2002:22).
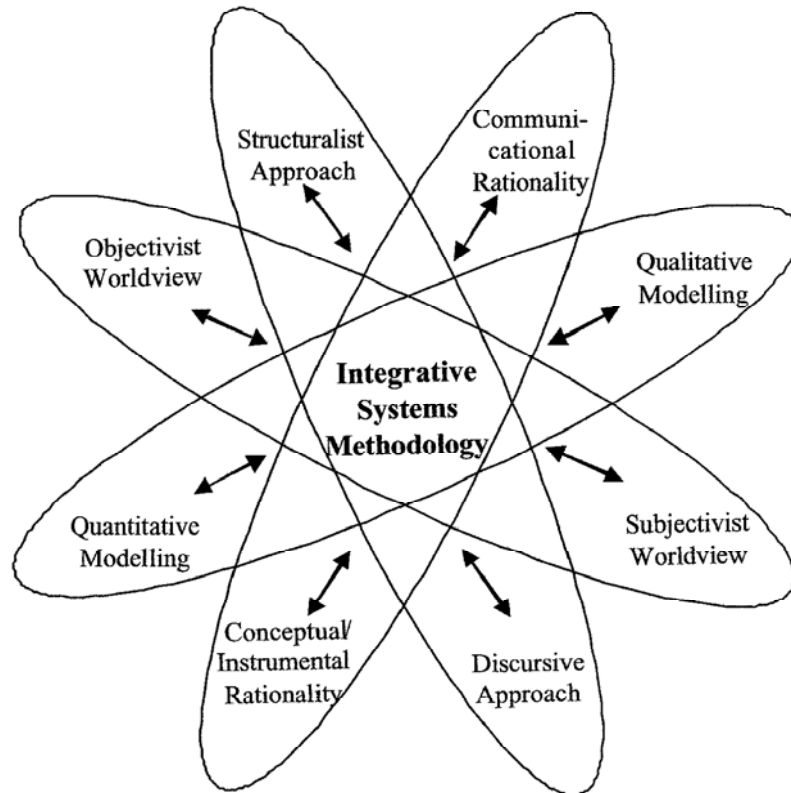
Figure 4.1: The polarities framework of Integrative Systems Methodology (ISM) (**Integrative Systems Methodology.** Schwaninger 2002, WWW.EOLSS.COM, Encyclopedia of Life Support Systems, Unesco, Copyright 2004, with permission from Eolss Publisher Co Ltd).

The Integrative Systems Methodology suggested by Schwaninger, particularly the polarity framework, explains why this study cannot be exclusively positioned into one of the traditional paradigms, since it combines research approaches that are based in different paradigms. Although ISM offers a methodological framework for dealing with complex issues and to attain requisite variety (Schwaninger 1997) it cannot resolve paradigm conflicts that may evolve if theories and results of different paradigms were compared, for example findings of System Dynamics and Econometrics studies (e.g. Meadows 1980, Andersen 1980). But it may help see those findings as complementary rather than as opposites and facilitate the dialectic search for social policy conclusion.

This discussion gives evidence that the unifying paradigm underlying this work still needs to be specified. One important inherent working assumption of the study is, that the observed problem arises due to feedback mechanisms. Therefore, the following section will shed some light on feedback concepts in social and policy science.

The feedback-perspective

As we have seen in Krebs' feedback perspective on economic theory, the concept of circular causality can often be found - more or less explicitly - in social and policy science. Richardson (1991) recognizes two main lines in social science in the understanding and application of feedback concepts that grow out of five or six intellectual traditions: the servo-mechanisms thread and cybernetics thread. Figure 4.2 gives an overview of both the intellectual traditions and their representative authors, as well as of their relationship to the two feedback threads. Furthermore, it shows that the System Dynamics approach used in this work may be different in the feedback concept than other feedback-oriented system approaches.

BIOLOGY-MATH MODELS	ECONOMETRICS	ENGINEERING	SOCIAL SCIENCES	BIOLOGY-HOMEOSTASIS	LOGIC
		Ktesibios			Epimenides
		Heron		Hippocrates	
					'vicious' circle
		Drebbel			Leibniz
Verhulst		Watt	Hume		Boole
			Smith	Bell	
		Maxwell	Federalists		Cantor
			Malthus	Wallace	Venn
		Routh			
Lanchester		Hurwitz	Mill	Bernard	Russell
Pearl		Lyapunov	Ricardo		Whitehead
Lotka			Hegel		
Volterra		Minorsky	Marx		
Kermack & McKendrick	Frisch	Simon		Henderson	
	Kalecki		Dewey		
	Koopmans	Black	Thomas		
Richardson	Tinbergen	Nyquist	Radcliffe-Brown		Carnap
	Harrod	Hazen	Malinowski	Cannon	
	Sameulson	Bode	Bateson		
	Hicks		Merton		
Rashevsky	Kaldor	McColl	Keynes		Goedel
	Klein	James, Nichols, & Phillips	Skinner		
		Brown	Sorokin	Rosenbleuth	
			Myrdal		
			Lewin		

Goodwin
Phillips
Tustin
Allen

Cooper
Simon

Forrester

SERVOMECHANISMS THREAD

Wiener
McCulloch
Pitts
Von Foester
Deutsch
Ashby
Shannon
Von Bertalanffy
Boulding

CYBERNETICS THREAD

Figure 4.2: Intellectual traditions of the feedback concept in social science and their relationship to the servomechanisms and cybernetics thread ("Feedback Thoughts in Social Science and Systems Theory," G.P. Richardson, 1991, Page 93 by G.P. Richardson. Copyright 2004, Reprinted by permission of Pegasus Communications.)

Richardson identifies three main distinctive characteristics of the two conceptual threads. Their specification in the servo-mechanisms or cybernetics thread depends on the level of aggregation and the problem focus, as well as on the point of view. The main characteristics are portrayed in Table 4.3. The reader may get a more precise understanding of the issues and their specification in the servo-mechanistic thread when reading the description of the method of System Dynamics (see Chapter 4.1.2). The main objective of this presentation is to raise the awareness of the existence of the two distinct concepts that may have further implications, as discussed below.

Servo-mechanisms thread		Cybernetic threads
Aggregate systems, endogenous	Level of aggregation, point of view	Focus on single individual, groups or organizations, Exogenous-endogenous
Dynamic patterns of behavior, persistent policy structure	Units of description	Events, decisions, messages
Continuity, quantitative representations, Causal loop	Causal loop representation	Discreteness, linguistic representations, communication nets, message loop
The concept of the particular distance: "A particular distance is required, one that blurs events into patterns of behavior and perceives policy structure in the flow of decisions" (342).	The conceptual distance	Either a close or a very distant perspective

Table 4.3: Distinctive characteristics in the feedback views of the servo-mechanisms thread and cybernetic thread (adopted from Richardson 1991:333ff). Richardson (1991) offers a more sophisticated discussion of themes and issues that may even illustrate different worldviews of both threads.

Understanding differences in the loop perspectives helps to clarify the position of the present research and explains differences in insights. Being aware of the trade-off and the price that has to be paid when choosing the servo-mechanistic thread is important. Insights about patterns of behavior and policy structure have to be paid by skipping insights of individual events and decisions and subsequently point estimates. Hence, this understanding seems to be an important requisite when comparing different theories and derived policy implications, as well as different paradigms in model testing. Furthermore, for assessing the choice of the method and the servo-mechanistic loop-perspective, it would be important to assess how well loop polarities, compensating feedback and internal dynamics in a multi-loop, non-linear system could explain the investigated real world problem.

The objective of this section is both to shed light on underlying paradigms of the research approach and to position this work appropriately. It is evident that the present study cannot be positioned in one of the traditional paradigms emphasized by Burrell and Morgan (1979), but fits both in the Integrative Systems Methodology framework suggested by Schwaninger (1997, 2002a) and in the contemporary agent-structure debate in sociology (see Lane 2001). Most importantly it shows that the study is based on leading working

assumptions that are inherent of the servo-mechanism thread (Richardson 1991) of feedback concepts of social and policy science.

4.1.2   System Dynamics and Group Model Building

"We are coming to realize that the interactions between system components can be more important than the components." Forrester (1961:14)

In the following section, the basic characteristics of System Dynamics are explained. Furthermore, an overview of Group Model Building - a technique that aims to build System Dynamic models directly with groups - is given, since elements of this technique were also applied, in the present study. The objective of this section is to provide the reader with enough information about System Dynamics and Group Model Building to facilitate comprehension of this study's research process, the suggested System Dynamics model as well as the derived insights[38].

The most important foundation for System Dynamics is the concept of information-feedback systems as stated by Forrester (1961), the founder of the field in his seminal work "Industrial Dynamics" in 1961.

> *"An information-feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions" (14).*

He observes that

> *"Systems of information-feedback control are fundamental to all life and human endeavor, from the slow pace of biological evolution to the launching of the latest space satellite" (15).*

Since then System Dynamics as a generic methodology has been applied in many domains of research including theory building in social science, economics, in biology or in psychology. In the context of social sciences, System Dynamics can be described as a computer-aided approach to policy analysis and design that focuses on dynamic problems arising in complex social, managerial, economic or ecological systems (see Richardson 1996:656).

The previous chapter mentioned the distinguishing characteristics of the *endogenous point of view* that allows focusing on dynamics over time in complex systems. The conceptual tools *feedback loops polarity* and *dominance* as well as the *stock and flow-syntax* allow analysis of dynamics

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[38] The following basics books on System Dynamics can be suggested for readers interested in modeling Richardson and Pugh (1981) and Sterman (2000). The best source providing an overview of the activities in the field can be found in "The System Dynamics Review". A very useful collection of papers can be found in Richardson (1996). Texts on group model building providing methodological guidelines are provided by Richardson and Andersen (1995), Vennix (1996), Richardson, Vennix et al. (1997). For an informative description of an exemplary case study working with group model building see Zagonel (2003) and Zagonel (2002) for an award winning paper about group model building and tensions between representing reality and negotiating a social order.

of systems. Subsequently, the identification and specification of loop polarity and dominance focus on dynamics, and stock and flow tools help analyze the structure creating these dynamics.

In the following section the conceptual tools are described and illustrated in a small "Chickens Crossing the Road"-model – which demonstrates the dynamics in a chicken-population rising from birth and death controlled by two feedback loops (see Figure 4.3). A feedback loop is composed of two or three kinds of variables: the rate, the level and the auxiliary variables. The decision point (e.g. the rate equation – *<birth-rate of chickens>*) within a feedback loop structure controls the flow into a stock. The level variables (e.g. *<chickens>*) are accumulations or integrations such as the number of people in a municipality. They are the memory of a dynamic system and the sources of its disequilibria and dynamic behavior. The rates of flow cause the level to change. The rate equations are the statements of system policy. They determine how the available information (from the level and the auxiliary variable) is converted to change the levels. They are integral functions representing the flow per time unit (e.g. chicken/month).

All dynamics arise from two types of feedback loops, positive (self-reinforcing) or negative (balancing) loops, indicated by plus or minus signs (see Figure 4.3). On the one hand, positive loops generate processes that generate their own growth. On the other hand, negative loops describe processes that tend to be self-limiting, that seek balances and equilibrium.

The figure above illustrates a positive loop guiding the chicken population growth: More chicken lay more eggs, which hatch and add to the chicken population, leading to still more eggs a.s.o. If this loop were the only operating loop the chicken population and the fresh eggs per month would grow exponentially.

Negative feedback structure ...   ... controlling decline in chicken population

fraction of chicken
dying due to road
crossing per month

(Stock/
Level)

Chickens

road crossing
death rate

Chickens dying

200

150

100

50

0
    0 1 2 3 4 5 6 7 8 9 10 11 12
                    Time (Month)

Chickens : chickens dying   chick
road crossing death rate : chickens dying   chick

This model structure shows a negative loop. An increase in the chicken population leads to more risky road crossing increasing the road crossing death rate, which causes to decrease the chicken population. If this were the only loop acting the number of chicken would gradually decline.

Interacting feedback loops –   - loop dominance deter-
                                      mines the resulting be-
                                      havior

fraction of chicken
dying due to road
crossing per month

(Stock/
Level)

(Rate/Flow)   Chickens

birthrate of   road crossing
chickens   death rate

hatched
chicken per egg
          +

(Auxiliary/
Constant/
Converter)

(Connector)   fresh eggs per
                 month   +

                              eggs per
                              chicken per
                              month

The question arises, what happens when both loops are operating? In order to understand the dynamics that arise from the interactions of these loops, System Dynamics models are helpful – showing changes in the dominance of interacting loops.

Figures 4.3: Positive and negative feedback loops in the simple chicken and road-crossing model (adopted from Sterman 2000:13).

Group Model Building

In the nascent stages of system dynamics as a field, the importance of involving clients in the model building process was emphasized (Forrester 1961). System Dynamicists acknowledge that effective learning from models occurs best when decision-makers participate actively in the development of the model (Sterman 2000:36). Sterman highlights the various tools and techniques facilitating clients' involvement such as causal loop diagrams, policy structure diagrams, interactive computer mapping and structuring and soft system techniques. Furthermore, as highlighted by Zagonel (2003) a line of research and practice exists that is termed Group Model Building. He refers to the body of work by Richardson, Andersen et al. (1992), Richardson and Andersen (1995), Vennix (1996), Andersen, Richardson et al.

(1997), Rouwette, Vennix et al. (2002). Group Model Building focuses on active client-group engagement, most importantly in the conceptual phase. In reviewing this research Zagonel (2002) traced a genealogy of Group Model Building from the perspective of the Albany approach. In his analyses he shows how the method of Group Model Building evolved from two schools of thought, the policy and the decision thread as depicted in Figure 4.4.
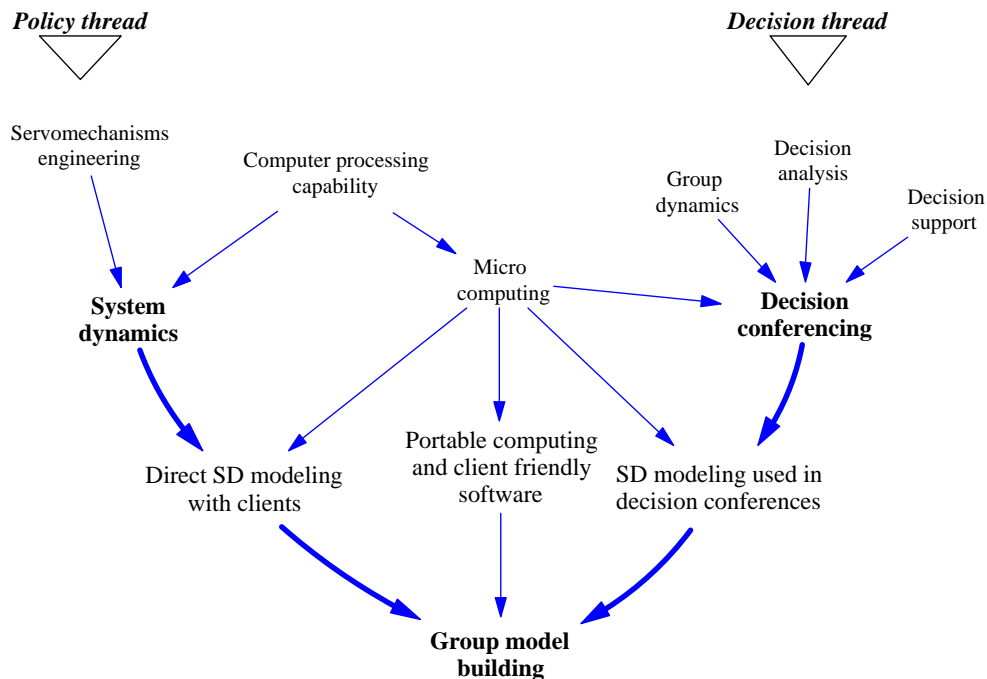
Figure 4.4: A genealogy of Group Model Building (Zagonel 2002); reprinted with permission from A. Zagonel, 2004.

He points out that the influence of both schools of thought leads to two inherent objectives of Group Model Building: decision or process oriented objectives and policy or content oriented objectives.

"Decision or process oriented objectives in Group Model Building may be stated as accelerating a management team's work, problem structuring and classification schemes, generating commitment to a decision, creating a shared vision and promoting alignment, and creating agreement or building consensus about a policy or decision. Alternatively, policy or content oriented objectives may be stated as improving shared understanding regarding the system or problem at hand, system improvement, and system process and outcome change. These involve changing the mental models of individuals in the group or organization, guided by insights produced using the modeling tools and methods" (Zagonel 2003:3).

He concludes that Group Model Building interventions strive to create both a shared understanding of an interpersonal or inter-organizational problem in the form of a *boundary object* and a *micro-world* representing a model of the "reality" that is useful for policy analysis or organizational redesign (Zagonel 2002:43).

A case study using Group Model Building to inform welfare reform policy-making in New York State gives evidence that this approach improves implementation processes and has positive effects on vertical (state-local) relations and horizontal teamwork (cross-agency team work) as well as on goal alignments. The following statement of a commissioner participating in the model building process illustrates those observations (see Zagonel 2003).

> *"With welfare reform, everyone's role is changing. For us at the state level, we have to stay out of the business of dictating how things get done at the local level. The modeling project is a good example of this kind of positive change in state/local relations and cross-agency teamwork. In the past, we probably would have told counties – in great detail and with incredible specificity – how we wanted them to implement welfare reform. Now we are making every effort to provide sophisticated, yet practical tools such as the welfare reform simulator, that local communities can use to think through policy implementation and arrive at their own solutions."*

Although the Group Model Building approach is not of central interest to the present study, some of its methodical elements are used in order to create a shared boundary object and a micro world. Although the SD-SWM-model does not explicitly address a concrete reform program, it is designed as a decision support tool to inform discussions of solid waste management strategies involving the relevant governmental authorities and entrepreneurs. Steps, methods and techniques implemented are reported in Chapter 4.3 (Integrative Systems Methodology and research design).

4.1.3   Gaining confidence in System Dynamics models

The two underlying objectives of building and running a computer model - to increase inter-subjective understanding (model as a theory) and to inform decision-making (modeling for learning) – should finally lead to better decisions making. Therefore, qualitative aspects of gained insights and validity issues are crucial. However, a simulation model cannot be verified or validated definitely since it is based on assertions about the empirical world and not on pure analytical statements – that are propositions derived from axioms of a closed logical system. Therefore, Sterman (2000) concludes "all models are wrong" (846).

All the same, social scientists use different concepts to define validity. Finlay and Wilson (1997) identify a common agreement across disciplines saying "validity is a measure of the goodness of a final product or outcome and that it involves judgment about the state of an experiment or system. Validation is the process by which this validity is determined" (170). In relation to decision support systems (DSS) such judgment involves utility aspects: "It is defined as the process of checking the extent to which the DSS developed to allow experimentation on a surrogate world is appropriate to the task in hand" (170).

According to Barlas (1996) two different types of models should be distinguished when considering validation criteria: *black-box models* (correlation models that are purely data driven) and *white-box models* (theory like models that are causally descriptive). Black box models such as time-series or regression models are assessed to be valid if their output matches the real data. The claim of the causal structure is not "validated". Alternatively, "a

white-box model, being a 'theory' about the real system, must not only reproduce/predict its behavior, but also explain how the behavior is generated" (186). Since System Dynamics models fall in this category they must generate the "right output for the right reason" (Barlas 1996:186). Reviewing the validity concepts in major System Dynamics articles, Barlas and Carpenter (1990) found that model validation is a gradual process of "confidence building" including a continuum of usefulness.

Furthermore, Meadows (1980) highlights that statistical estimation procedures are seldom used in System Dynamics because "model output is read not for quantitative predictions of particular variables in particular years but for qualitative behavioral characteristics" (36). It is more important to identify the crucial variables and get the model structure right than to omit a variable due to missing numerical data. Forrester (1961) puts it as follows:

> *"This means that model building and model validation do not stop at the boundary where numerical data fail. It means that both have full access to the vastly richer sources that lie in the nonquantitative areas of business management. By hypothesizing quantitatively about these areas, the day may be hastened when firmer facts and measurements are available"(129).*

The process of iterative model testing

Testing the model is an iterative process that aims to build confidence in the model. The logic of model testing is illustrated in Figure 4.5. During the process of model development each new single module will be tested. First, the structure must be plausible and second, it must produce the hypothesized behavior. This involves simulating the single module and parameter testing. Third, if the single modules produce the right behavior for the right reason, the whole model as far as it is formulated will be tested. This includes linking the different modules and assessing the overall model behavior. Final, when the structure is perceived as adequate, the accuracy of the behavior and the exhibited pattern is tested.
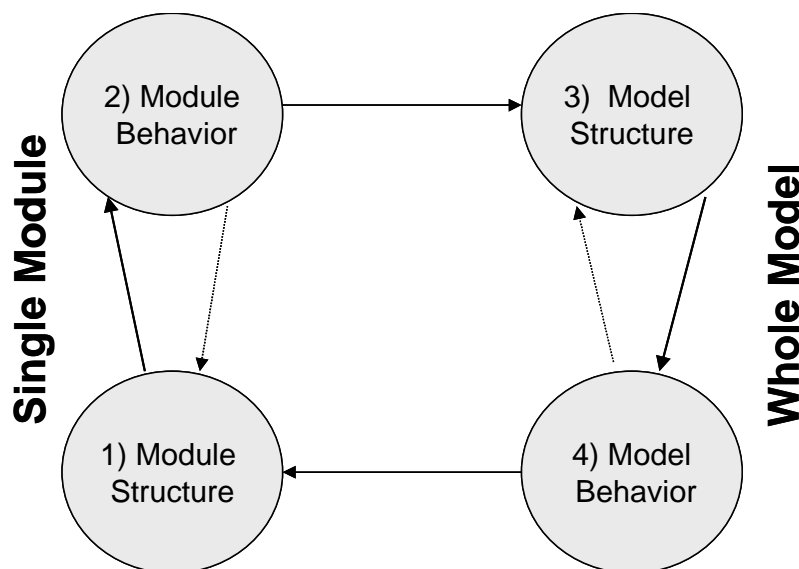
Figure 4.5: Logical sequences in the iterative model testing procedure (Schwaninger 1999).

In the literature different tests have been suggested (for an overview see Barlas (1996), or Sterman (2000:845f) that can be grouped together either focusing on structure validity or on behavior validity.

The structure validity test-cluster includes direct structure tests and structure oriented tests. *Direct structure tests* aim to assess if the model structure is consistent with the relevant descriptive. Are the relationships plausible to the experts in the systems or are they in line with causal assumptions tested in previous research? Are the dimensions consistent? Structure-oriented behavior tests include simulation of the model, such as extreme conditions tests and behavior sensitivity tests, but also causal tracing.

The behavior pattern test cluster assesses the correspondence of the endogenously generated model behavior with observed behavior in the real world. They include quantitative comparison with statistical tests such as Theil's inequality statistics but also qualitative ones such as plotting model output data against real world data, and comparing the mode of behavior. Finally, for behavior tests, sensitivity analysis, and policy tests are crucial.

Figure 4.6 depicts the test clusters and refers to some available tests.
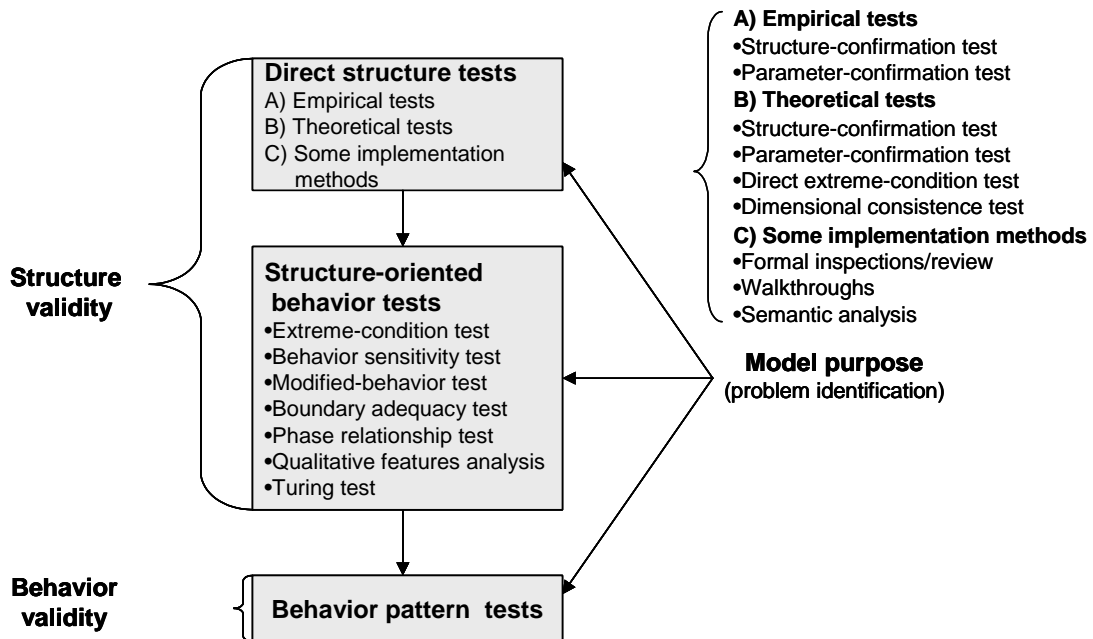
Figure 4.6: Test objectives and test clusters (adopted from Barlas 1996:189)

Although a variety of tests exist, it would not be efficient to conduct all of them (see Forrester 1999). The degree of confidence and purpose of the model guide the choice of

relevant tests[39]. However, the test philosophy and the available tests illustrate that testing a System Dynamics model is a sophisticated process aiming to assess various aspects of logical coherence and consistency, as well as correspondence with the observed real world behavior.

Figure 4.7 illustrates that this process inherently includes falsification and refinement procedures testing causal assumptions. Although not all available tests have to be conducted, it is crucial to establish confidence in both the structure as well as the overall behavior of the model.
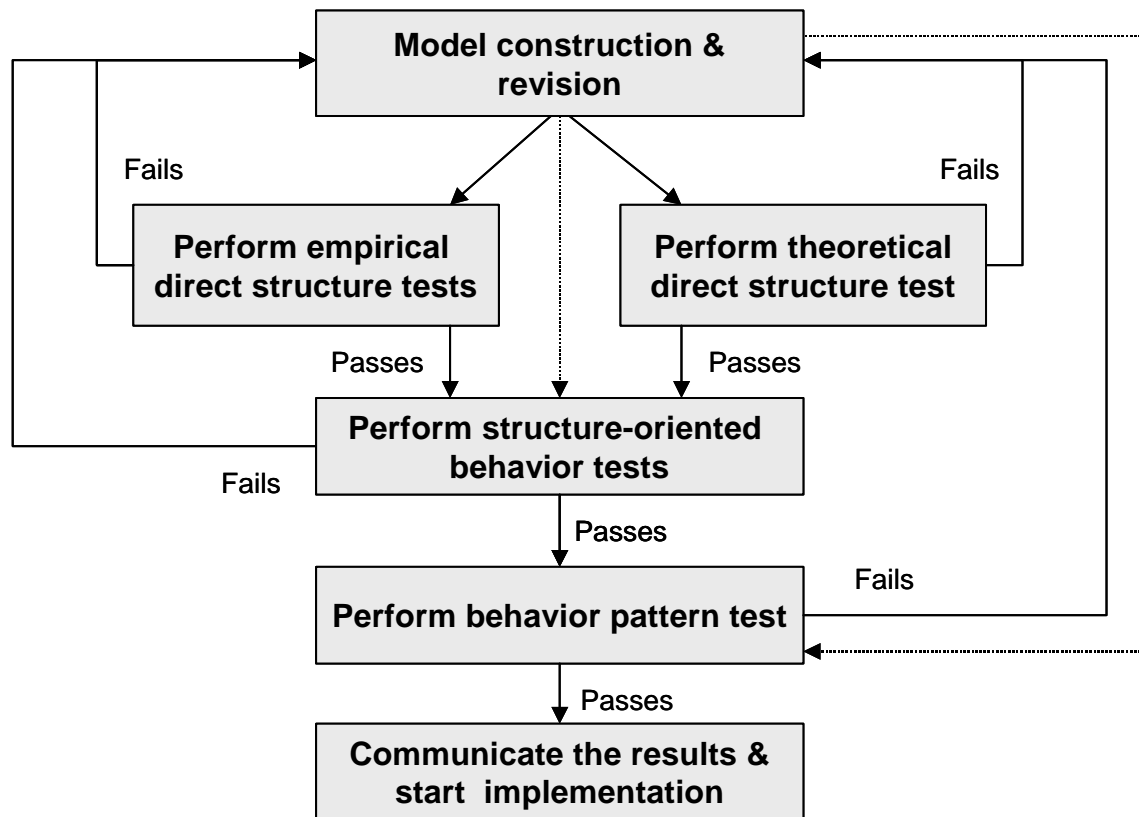
Figure 4.7: The inherent falsification and refinement procedures in SD-model testing (adopted from Barlas 1996).

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[39] For a discussion about the different modes of application of system dynamics and how they relate to different aspects of model validity, see Barlas (1992), Wittenberg (1992), Sterman (1992), Radzicki (1992), (Lane (1995).

4.2   The research strategy

4.2.1 Towards a System Dynamics model: computer-assisted theory building

Since the present study aims to develop a System Dynamics model explaining the observed phenomena in solid waste management, an explorative research strategy is chosen (Bortz and Döring 2002). According to Zikmund (2000) explorative research is often seen as a preliminary step that helps define the nature of a (management) problem whereas only subsequent conclusive studies could offer answers necessary to determine a course of action, in business research. Zikmund (2000) points out that "this is never the purpose of exploratory research" (102). In this study, the explorative research approach is seen as a research strategy towards theory building, that includes a systematic screening and generation of alternative concepts (see Bortz and Döring (2002:355f.)). In line with Bortz's understanding, the suggested System Dynamics model is seen as a formalized theory and a quantitative computer model that simulates the hypothesized processes. Furthermore, Zagonel's (2002) comprehensive description of the System Dynamics model building method highlights that it aims to come up with conclusive statements and policy recommendations:

> *" The System Dynamics model building method can be described in phases that begin with a clear definition of the problem of interest, and end with a conclusive statement about this problem, containing policy recommendations aimed at its solution or mitigation" (3)* referring to Richardson and Pugh (1981: 15f).

This indicates that the computer-assisted theory building approach aims to push the cognitive interests further including issues of policy implementation. However, the present model development process starts with an exploratory phase that is guided by different heuristics helping to design the context of discovery[40] in a systematic manner, subsequently increasing the probability to come up with a useful model.

Context of discovery

In order to establish a broad basis for the iterative model development process a theory-based exploration is chosen including theories and concepts that have been scientifically developed and tested (see Chapter 3 Previous research and theoretical grounding), as well as subjective mental models representing theories in use (Alltagstheorien) (see Chapter 4.3 Integrative Systems Methodology and research design). The literature review and the conducted workshop help structure the research topic, and to define the problem synthesized in conceptual heuristics. Relevant terms and variables are identified and

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[40] Reichenback (1938) distinguishes two main issues in the research-process: the *context of discovery* referring to conditions that are likely to lead to seminal theoretical concepts and the *context of justification*, referring to techniques that help justify theoretical statements. Ulrich and Hill (1979) also emphasize the *context of application* dealing with questions about utility and justification of scientific propositions for design and implementation. In this context scientific propositions are normative and therefore they should be stated as means-end statements.

specified, and first causal assumptions are sketched (see Chapter 5.1). Furthermore, the framework "a *Feedback Perspective on Human Behavior and Public Policy"*, (see Chapter 3.7) is used as a heuristic and substitute of a disciplinary focus. It helps to conceptualize the model in such a way that the main relevant aspects of the multifaceted issues of solid waste management could be integrated (see Chapter 5.2).

Computer-assisted theory building - an iterative process of falsification and refinement

The computer-assisted theory building process within System Dynamics integrates the different issues of the *context of discovery* and *justification* in one process, since the proper model building process is iterative in a high frequency.

> *"It ... involves a number of passes through the stages of conceptualisation, formulation, simulation and evaluation. At each successive pass, parts of the model are reformulated and refined, perhaps even deleted, and other structure is added. The purpose of the iterative process is eventually to produce a model highly consistent with the real system, well suited for its purposes, and well understood" (Richardson and Pugh 1981*:293)

Schnell (1990) emphasizes that simulation models are more precise than theories described in everyday language or mathematical formulations, since the formal syntax provides precision. A vague theory can hardly be translated in a computer model producing the given reference mode. In a computer model the theoretical assumptions are made explicit (see 118f).

Hanneman (1988) highlights the language used in System Dynamics as a very powerful tool for stating theories about dynamics.

> *"Because the language has a limited vocabulary and syntax, there is much less ambiguity (for both the theorist and the audience) about what is being said when the formal language is used. ... Not only does the syntax of the language aid in structuring the theorist's thinking, but it allows for the easier statement of extremely complicated multivariate and over-time relations" (325).*

A further characteristic of System Dynamics models is that every variable has a real world meaning and is specified by units. Hence, the formulated relationships are clearly operationalized thereby representing well-specified hypotheses.

Regenerative exploration using elements of the Group Model Building method

In real-world problem solving and design, purposiveness (of tools) depends on purposefulness (of people using tools)[41]. (Ulrich 1983:332)

As described above, different research strategies are chosen in order to design the exploration in a systematic way. Furthermore, the iterative model building process helps to develop a precise theory that generates a model behavior corresponding with the observed real world data. However, in order to develop a useful model that may serve as a decision-support tool, firstly, it must be able to address the relevant policy questions, secondly, decision-makers should be informed about its "mechanics" and the insights it provides, but most importantly they should feel confident about the model.

In order to address these specific requirements a regenerative explorative research strategy as suggested by Schwaninger (1996b) is chosen. This strategy refers to a research design in which feedback between the researchers and the stakeholders and decision-makers are systematically integrated in the research process in order to increase the validity of the exploration. For this study, elements of the method of Group Model Building (Richardson and Andersen 1995, Vennix 1996, Richardson, Vennix et al. 1997, Zagonel 2002) are adopted (see Chapter 4.1.2 and 4.3).

4.3   Integrative Systems Methodology and research design

The design of this research project is not only guided by the phases of the System Dynamics modeling method[42] but also by the Integrative Systems Methodology (ISM) suggested by (Schwaninger 1997). It is the methodological reference framework of this study. The advantage of referring to this encompassing ISM-framework[43] is seen in the improved comparability of various integrative systemic approaches including subjective and objective views and other complementary viewpoints (see also Figure 4.1). By implementing elements of the Group Model Building method in the present study and in follow-up workshops with decision-makers, subjective perspectives and issues such as learning-processes are integrated.

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[41] According to (Ulrich 1983) *purposiveness* refers to effectiveness and efficiency of means or tools and *purposefulness* to the critical awareness of self-reflective humans with regard to ends or purposes and their normative implications for the affected.

[42] An overview of the proposed phases of the System Dynamics modeling method suggested by different authors with slightly different focus points can be found in (Zagonel 2002). They mainly emphasize the following phases: 1. Problem recognition, 2. System conceptualization, 3. Model representation, 4. Model behavior, 5. Model evaluation, 6. Policy analysis, 7. Model use (referring to Andersen and Richardson (1980). Sterman (2000) emphasizes the dynamic hypothesis instead of the conceptualization phase and summarizes the two phases "model representation and behavior" in the phase "formulation".

[43] This framework builds on previous research on Network Thinking (Gomez and Probst 1987; Gomez 1995, Vester and Hesler 1988, Ulrich and Probst 1991).

However, the study also strives for objectivity by building a quantitative simulation model through which its assumptions are made clear and can be falsified or refined subsequently.

Besides the aspiration of integrating complementary viewpoints in the research approach, ISM emphasizes "the context in which the problem at hand and its solution are embedded" (Schwaninger 1997:112). This focus is in close alignment with the fundamental theoretical aspects of this work: environmentally relevant behavior focusing on constraints and opportunities as the main precondition of environmentally responsible behavior. The following table gives an overview of the phases and steps distinguished in ISM (see (Schwaninger 1997) and in the System Dynamics modeling method (Andersen and Richardson 1980).

Phases (see Chapter)	Steps	Tasks	Phases according to the System Dynamics modeling method
Modeling (3.1, 3.7, 5.1-5.4)	1. Step	Ascertaining relevant perspectives, their goals and factors critical for attaining them	Problem recognition
	2. Step	Surfacing issues	System conceptualization
	3. Step	Elaborating models	Model representing
Assessing (5.5)	4. Step	Apprehending the dynamics of the system	Model behavior
	5. Step	Simulating and exploring scenarios	
	6. Step	Interpreting and evaluating simulation outcomes	
Designing (5.6)	7. Step	Ascertaining control levers	Policy analysis
	8. Step	Designing strategies/action programs	
Change (Follow up workshops)	9. Step	Realizing strategies	Model use

Table 4.4: Ideal types of phases and steps according to Integrative Systems Methodology (ISM) and SD-modeling method.

Finding the right research partner – determining the right municipality

The research design of the IP "Strategies and Instruments" was guiding the sample of the municipality participating in the research project. The first criterion was willingness to participate and cooperate in transdisciplinary research dealing with issues of sustainable development at the local level. A second criterion was experience with projects aiming to promote a sustainable development.

Hence, the municipality of Ittigen was chosen. It is located in the agglomeration of Berne (Switzerland) with about 11'000 inhabitants. It is recognized as taking innovative approaches in its environmental policies. Ittigen, for example, was participating in the light electro mobiles (LEM) pilot and demonstration program and in the Global Action Plan (GAP), as well as being the first municipality in Switzerland that implemented the environmental norm ISO 14001 (see www.ittigen.ch). The authorities of Ittigen were willing to gain a deeper understanding of factors determining environmentally relevant behavior of their citizens.

They were also willing to provide the required information about their municipality for this investigation[44].

In the following sections, the research process is described. The section is structured according to the phases distinguished in ISM.

Modeling

Step 1: This first step was carried out in the preliminary study. In order to trace the relevant perspectives, a literature review on environmentally relevant behavior and on environmental policy was conducted. In addition, the gatekeeper[45] of the client group helped to determine the relevant actors that should participate in the model building process (see Appendix B2 Selecting the experts). Three Group Model Building-sessions were held in order to map problematic causal chains in the municipality (for the scripts see Appendix B3-5). Ten experts, representatives of the local government, the local administration and consulting firms responsible for the local management and policies of energy, traffic, water/waste water, solid waste and consumption were involved. They shared their mental models about problems of environmental policy in order to elicit main impediments to compliance - in a broader sense. The aim was to reach consensus about the causes and consequences of environmentally harmful behavior of the inhabitants. Based on the subjective models[46], an overall qualitative "outline" describing responsible environmental behavior *"The Framework Model REB"* was synthesized (see Bruppacher and Ulli-Beer (2001b), Ulli-Beer (2002)) and Chapter 5.1.1). The findings from the literature review and from the workshops resulted in the framework *"A Practical Guide for Facilitating Environmental Policy Compliance"* specifying important terms and variables of the context (see Chapter 5.1).

In a parallel process the research team of the "IP Strategies and Instruments" were discussing a theoretical framework about human behavior that resulted in *"a Feedback Perspective on Human Behavior and Public Policy"*. Its original idea can be traced back to a "model building session" with a small group of three psychologists and an economist. In the above-mentioned model building sessions the communication tool and modeling software STELLA[47] was used.

Step 2: These first steps were followed by informal discussions with the authorities responsible for local solid waste management. The focus was on the content of specific phenomena of solid waste management. Those discussions helped surface and identify main issues of solid waste management (see Chapter 5.3). Subsequently, the objectives of the main study could be specified (see Chapter 2.1.1 and 5.3.1).

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[44] The author highly appreciates the commitment and the support as well as the engagement of the authorities in this research project that was carried out over a long time span of about six years. Without their cooperation this work could never have been written.

[45] For an explanation of different roles in Group Model Building see Richardson and Andersen (1995).

[46] The transcripts and the maps of the elicited mental models are accessible through the author.

[47] STELLA is a software program and a registered trademark of High Performance Systems, 45 Lyme Road, Hanover, NH 03755 U.S.A, (see http://www.hps-inc.com/stellavpsr.htm).

Step 3: Based on the heuristics and reference modes of the local solid waste management system, the concrete model concept and its boundary were developed, and the dynamic hypothesis was posted. The author herself developed the SD-SWM-model with the support and mentoring of experienced modelers[48]. The model building process evolved from a simple first order-loop "concept model"[49] simulating both the possible waste disposal alternatives of households and amounts of the different waste qualities. It was by no means a linear process but rather a long search for the right focus and approach – till a promising starting-point was found or the real causes and dynamics of the observed phenomena were discovered. From this point on, the model-development process was guided by the developed heuristics and model concepts. Sector by sector were formulated and iteratively tested.

Assessing

Once the basic model structure was elaborated, different test procedures were conducted in order to fully understand the dynamics of the system and to test its robustness, consistency and correspondence with the real data. Those steps are extensively documented in Chapter 5.4.

Designing

In this phase different kinds of policy-experiments were designed and conducted including back-casting and forecasting experiments under different scenario-conditions. Furthermore, well-chosen sensitivity tests were processed and interpreted. Important policy-levers were identified. For the quantitative modeling process the software Vensim[50] was used. For the detailed description see Chapter 5.5 and 5.6. In the middle of this phase a further meeting with the core group of the modeler audience was held. This core group included two representatives of the local government, and one consultant, as well as a recycling-entrepreneur. Their feedback was quite encouraging since the model structure, its assumptions, its dynamics and the derived insights seemed plausible to them. Furthermore, they suggested expanding the audience for the next meeting including more representatives from other municipalities as well as state and national agents.

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[48] I cannot express sufficient gratitude to the Albany System Dynamics Group for all the support they were giving to me not only when the dynamics of the model started to encroach me. I am deeply indebted to David Andersen, George Richardson, Rod Mac Donald, Aldo Zagonel, Mohammad Mojtahedzadeh, and Vedat Diker for their mentoring and encouragement.

[49] According to Andersen and Richardson (1997:117) concept models are typically bad first cuts at system dynamics models that pursue mostly pedagogical purposes and are often used in Group Model Building approaches. They should give direction to robust and appropriate formulations for the problem at hand.

[50] Vensim is a software program and a registered trademark of Ventana System ,Inc, Co Jacob Gates Road, Harvard, MA 01451 (see http://www.vensim.com/software.html).

Changes

Future workshops that would include decision-makers from different governmental, administrative levels, and other relevant stakeholders and decision-makers in order to test the usefulness and adequacy of the developed tool and derived insights, have been planned. However, they are beyond the scope of the present study.

5   Results - The SD-SWM-model

Thus far, the theoretical background of this investigation, the broader context of environmentally relevant behavior and public policy, as well as the research approach has been described. While the main goal of the preliminary study is to highlight measures that improve conditions for environmentally sound behavior of citizens, the overall goal of the main study is to develop a SD-SWM-model in order to test, as well as to evaluate strategies and policy combinations. However, in both phase of investigation, the main issues under focus are the importance of factors or driving forces and their interaction describing environmentally relevant behavior.

In this Chapter, the results and products of the preliminary and main studies are presented. The first part of this chapter will show how the results of the preliminary are related to the results of the main study. In the second part of this Chapter the model-structure, its underlying assumptions, different tests and policy experiments as well as sensitivity analysis tests are documented.

In sum, this chapter will provide evidence that the model serves the purpose of policy analysis (addressing "what if"-questions) and decision support. Furthermore, it presents important insights into the dynamic interactions between citizen choice and preferences and public policy initiatives *resulting either in policy resistance or compliance*. The implications referring to the problem statements are discussed in-depth in Chapter 6.

5.1   Results of the preliminary study: Reaching a consensus about driving forces determining consumption patterns and environmental impact

This section presents the findings of the preliminary study. "Theories in use" elicited in the workshops and *"the List of Important Characteristics for Public Policy"* identified in the literature review are integrated, resulting in the framework *"a Practical Guide for Facilitating Environmental Policy Compliance"*. The framework terms *clusters of key variables*, and specifies their relation to the identified helpful preconditions, as well as bears their direction of impact. Those first insights were published in Bruppacher and Ulli-Beer (2001b:292f). Hence, the following portrayal is an adjusted reprint of the relevant part of this publication.

Key factors for responsible environmental behavior

Based on the mental models developed by the participating experts and on research findings ten clusters of factors that are main influences on the individuals' intentions to act in more or less environmentally responsible ways were identified (see Table 5.1). There are five important clusters of external factors that influence the citizens' situational preconditions, and five important clusters of internal factors that influence personal preconditions.

A)	Relevant aspects of situational preconditions	B)	Relevant aspects of personal preconditions
1)	Social and political integration	6)	Understanding of inter-relationships
2)	Opportunities to act	7)	Personal audit
3)	Costs of living	8)	Convenience, laziness
4)	Capital expenditure	9)	Habits
5)	Social and legal norms	10)	Overall orientations (moral, values, environmental concern)

Table 5.1: Relevant aspects of internal and external factors influencing individual environmentally responsible behavior (Bruppacher and Ulli-Beer 2001b:293).

Figure 5.1 presents the *"Framework Model REB"* that includes the ten important clusters of factors influencing intention and their relationship to the hierarchical subsystems - *household consumption patterns* and *household metabolism:* Traffic choices, and purchase decision of consumer goods, as well as the emissions of long life equipments influence both the quantity and quality of household metabolism. The perceptions of the situation in the two subsystems (household metabolism and consumption patterns) again have an influence on intentions to act in a more or less environmentally responsible way. The perception of options and constraints influences consumption patterns that in turn influence household metabolism.

The intention to put more environmentally responsible behavior into practice can be formed or can be reinforced. As we can see in the qualitative model, presented in Figure 5.1, the intention to act in a more environmentally responsible way is regarded as a key factor in changing consumption patterns and subsequently decreasing household metabolism.

Model Responsible Environmental Behavior: Model REB
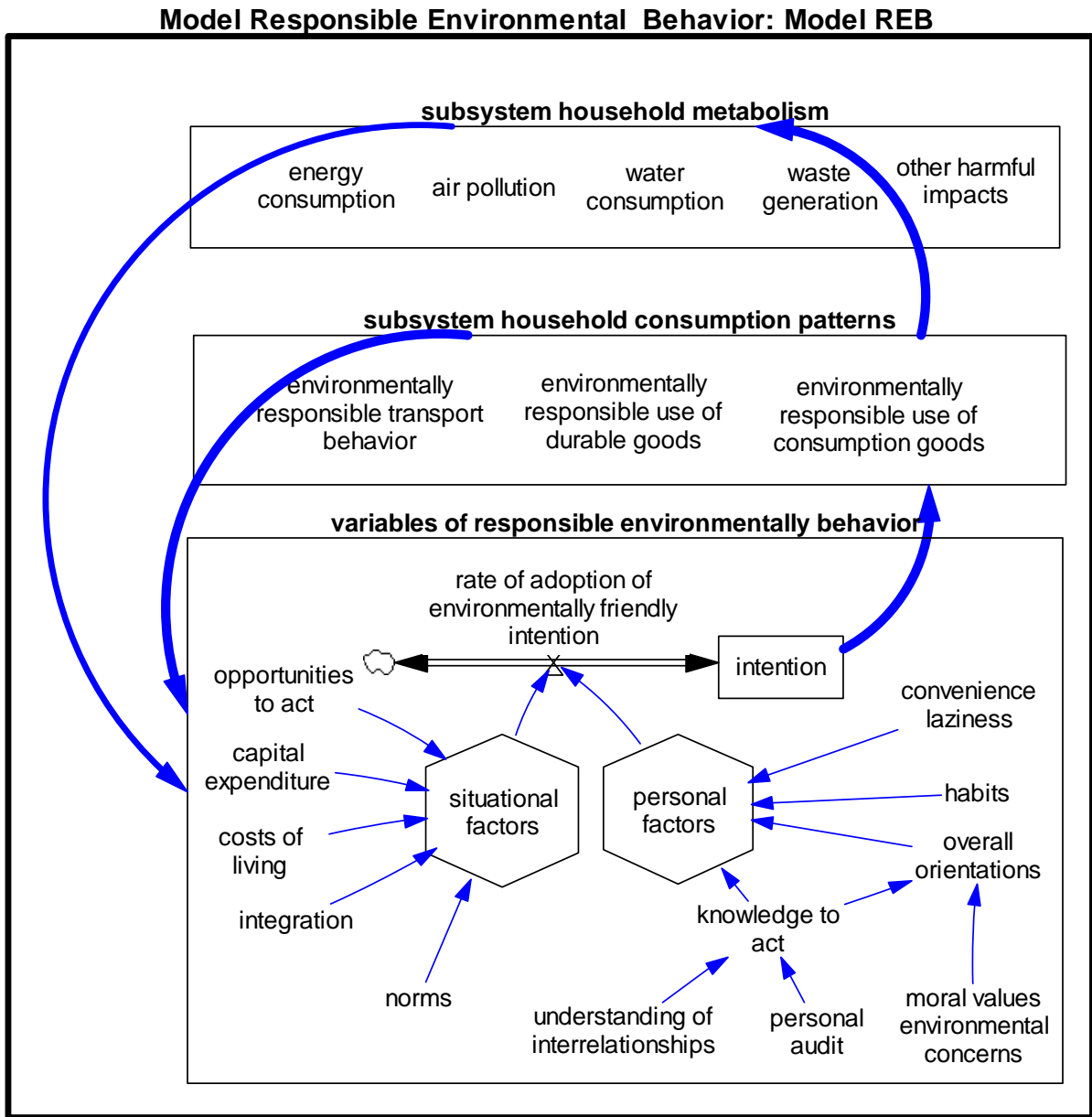
Figure 5.1: "*Framework Model REB*": Clusters of variables influencing responsible environmental behavior and its consequences on consumption patterns and environmental impact (adopted from Bruppacher and Ulli-Beer 2001b:294).

This model can help decide on designing political measures. The clusters of factors can be entry points for political interventions in order to change consumption patterns in a more sustainable direction, as shown in Figure 2. The groups of factors can be interpreted in two ways:

On the one hand, they can be interpreted as ...	On the other hand, they can be interpreted as ...
• groups of variables or factors influencing the everyday management of households, leading to **unsustainable** lifestyles; • groups of barriers to environmental sound action.	• groups of variables or factors influencing the every day management of households, leading to **more sustainable** lifestyles; • groups of resources, catalysts for environmental sound action.

The main challenge to politicians is to develop strategies including policy-packages that create and modify structures in the municipalities mobilizing resources and acting as catalysts for environmental sound behavior and lifestyles.

The relevance of these clusters is supported by a qualitative study investigating citizens' point of view (Bruppacher 2001a) as well as by the *"List Of Important Criteria of Public Policy"* that were identified in the literature review reported in Chapter 3.1.1. By combining the clusters and the *"List of Important Criteria of Public Policy"* not only will the meaning of clusters become more specific but the conditions under which it is likely that the identified clusters of variables may act as catalysts and resources rather than as barriers will be indicated.

Table 5.2 presents the unified framework *"a Practical Guide for Facilitating Environmental Policy Compliance "* combining the findings of the literature review on environmental issues with the findings of the Group Model Building workshops. When reading through the list, it becomes clear that a policy intervention may influence different variables, subsequently changing different kinds of preconditions. But these interactions and processes are still unclear. However, the framework may still be useful in guiding the model-building process. It may help capture the driving forces, the single components in the system partly explaining the observed phenomena in solid waste management. It guides the focus on the preconditions (context) in which choices are made.

The framework may also be functional for policy design. Schwaninger (1997) points out that "the problem is that problem solvers are focused on the problem"(112). This observation may also explain why some policies are doomed to failure since policy makers are not aware of inherent "obstacles" that produce policy resistance. The framework helps to enlarge a very narrow problem focus to the extent that preconditions of actions choices are systematically considered as well. Hence, policy programs can be designed that not only address the problem itself, but also aim at improving the preconditions for citizens' behavior change, subsequently overcoming policy resistance in the system and increasing the overall policy compliance. In conclusion this framework may also be seen as a heuristic for policy makers.

Clusters of relevant factors	Characteristics measures improving preconditions for environmental sound action (ESA)
Improving contextual, situational preconditions	
Social and political integration	• Promoting personal communication in social groups on ESA alternatives • Reducing the risk that environmentally sound behavior will be socially sanctioned or punished • Encouraging cooperation, participation, and voluntary agreements on environmental targets
Opportunities to act	• Boosting salience and attractiveness of ESA alternatives in reinforcing facilitating structures and weakening inhibiting ones • Creating ESA alternatives
Economic factors	• Promoting primarily those ESA alternatives which are neutral in cost and time demands • Avoiding and reducing high costs for the targets groups
Capital expenditure	• Encouraging farsighted planning which convert high-cost situations into low-cost situations
Social and legal norms	• Respecting personal autonomy • Respecting the level of environmental awareness in the community • Respecting prevalent normative and moral trends
Improving personal preconditions	
Understanding	• Facilitating an adequate perception of environmental problems • Visualizing environmental problems and risks • Delivering information about ecological facts in understandable ways • Touching emotional, natural, social, economic, and historical aspects of environmental issues • Pointing out information on energy and resource efficiency of appliances and durable goods • Promoting discussions on factual issues as well as on diverging interests and visions on occasions of referenda and new actions on environmental policy issues • Stressing factors and processes which influence environmentally undesired behavior
Personal audit	• Measuring and communicating individual parameters of environmentally relevant (energy) consumption • Illustrating causal effects of own and others' behavior and their short- and long-term consequences
Convenience and indolence	• Promoting primarily those environmentally sound product- and service-alternatives that are equally convenient as conventional ones • Stressing the value and attractiveness of environmental sound action
Habits	• Pointing out undesired routine behaviors • Hampering undesired behaviors • Modifying structure of production, distribution, and housing which generate harmful environmental side-effects e.g. high transport needs
Overall orientations	• Avoid evoking strong negative emotional reactions • Creating personal commitment • Consistent transformation of environmentally sound living situations

Table 5.2: *"A Practical Guide for Facilitating Environmental Policy Compliance"* including clusters of relevant factors and important criteria for improving environmentally relevant action (ERA) conditions.

5.2   From a feedback perspective on human behavior to a System Dynamics model for solid waste management

In the preceding section the reader was able to reconstruct how different approaches explaining environmentally sound behavior were explored and synthesized. That process resulted in two heuristics: in the above portrayed *"Practical Guide for Encompassing Public Policy Design"* and in the *"Framework Model REB"*. Furthermore, the framework *"a Feedback Perspective on Human Behavior and Public Policy"* was chosen as the overall guideline. It encompasses the ideas of the other two frameworks developed.

In the following section it will be illustrated how those general frameworks are transformed and specified in a System Dynamics model addressing observed phenomena in local solid waste management. Hence in this system inquiry, both kinds of environmentally significant behaviors are addressed:

- waste separation behavior of citizens, i.e., behavior that directly causes environmental changes and

- solid waste management policies[51] shaping the context, in which citizens waste separation behavior takes place.

The main purpose of developing those frameworks was to have a heuristic that sharpens the focus on important concepts and basic feedback processes that should be taken into account when conceptualizing the model. Indeed, it helps both to found the model building process on relevant concepts and to identify the relevant components of the system. While this framework strives to offer a broad heuristic identifying important concepts and general components, the concrete variables and parameters that must be included in the model arise directly from the specific issues and phenomena that are to be investigated (see also Forrester 1961:60). They are mainly determined in the model conceptualization phase (see Chapter 5.3).

While the decision on the specific, operationalized variables - that should be included in the model - is part of the iterative model-building-refinement process, the identification of important components of the system under study is guided by heuristics.

The following Figure 5.2 illustrates the identified important system components of the SD-SWM-model and how they fit in the framework *"a Feedback Perspective on Human Behavior and Public Policy"*.

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[51] In this statement the word policies refers to continues understanding of policy making representing policy decision rules that describe the behavior of decision-makers. It is in line with Forresters interpretation of policies that are guiding rules determining the changes in the state of the system (Forrester 1961:96f).
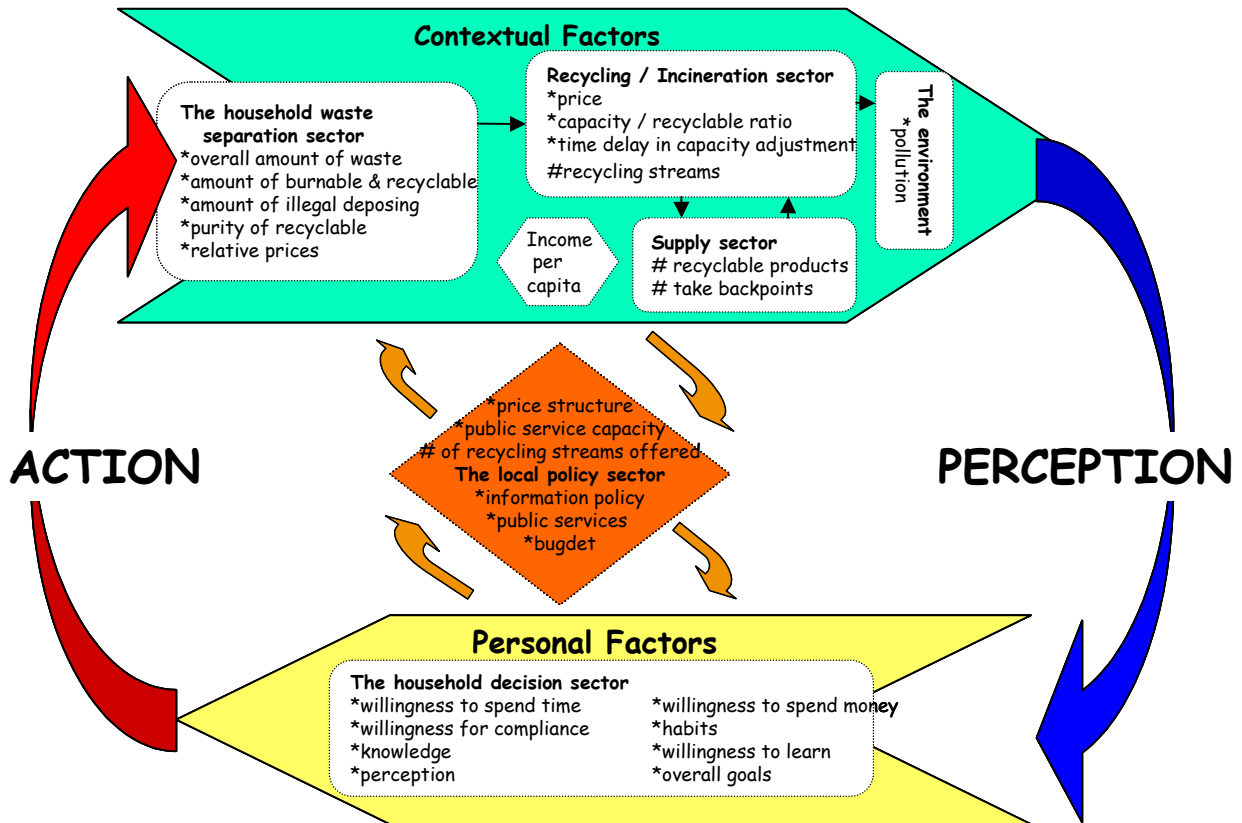
Figure 5.2: A feedback perspective on separation behavior and solid waste management.

The separation behavior of citizens is regarded as a result of the constant interplay between contextual (situational) structure and the personal characteristics of the citizens. Important personal factors that should be captured in the System Dynamics model are for example concepts representing the willingness to spend time or the willingness for compliance referring to the heuristic *"a Practical Guide for Encompassing Policy Design"*. They will constitute the household decision sector. The important physical components in the contextual structure are the overall amount of generated waste, the amount of inertia recyclable material, and the inertia amount of material that should be put for burning. Together with more qualitative situational factors such as relative prices between secondary and primary raw materials and purity of the recyclable material, they will constitute the household waste separation model. This sector provides important information of environmentally relevant household metabolism arising from the consumption patterns of citizens (see Figure 5.1: Model REB). The components in the Recycling / Incineration sector and Supply sector refer to the cluster of relevant factors determining situational preconditions such as opportunities to act or capital expenditure. Furthermore, the local policy sector includes both kinds of components influencing either situational factors such as the number of recycling streams or the price structure, as well as those influencing personal factors such as information policy. However, the effects of social relations are not represented in this view. The intention to separate waste emerges within the citizens as a result of individual values and goals and deliberation processes based on interpretation and appraisal of the situation. It can be

established in daily routine behavior. However, the exact consequences and the "success" of separating depends not only on the actor's skill but also on the concrete action context; hence on the preconditions (e.g. the quality and number of collection points). The citizens monitor the situation and adjust their intention to separate. The perceived success determines the cognitive monitoring and adjustment process. Subsequently, it influences the internal structure of the citizens transforming it in favor or against separating. The separating outcome also affects contextual structures such as collecting and recycling cost and the prices.

Kaufmann-Hayoz and Gutscher (2001a) describe this processes including social influences as follows:

"The outcome or result of actions is on the one hand perceived by the actors and appraised with respect to their goals, and it thus affects their internal structure; it has on the other hand an effect on the objective situation, it affects the external structure, the actors' (and other people's) surroundings"(24).

These feedback processes affect the policy sector in which the policies will be adjusted to the new situations in the overall solid waste management systems.

While it is widely recognized that such feedback processes are a fundamental feature of social systems (Richardson 1991), their significance and organizing power can only be captured if both the right components at the right place are recognized and their dynamics can be investigated. Hence, the framework offers the potential to identify and visualize important components of the contextual and the personal structure. However, its interactions, the dynamics and the processes explaining the observed phenomena have to be analyzed in a simulation model. Subsequently, important leverage points and the impact of policy interventions can be investigated.

5.3   Model conceptualization

We have learned how the different frameworks have led to the specific feedback perspective on environmental behavior and solid waste management; in the following section we will learn how the concrete questions and phenomena under investigation guide the System Dynamics model conceptualization. Furthermore, the assumed dynamic hypothesis that explains the observed behavior pattern of the solid waste management system will be made clear.

5.3.1   Problem statement

The problem addressed by the System Dynamics model is represented in the following questions:

What local policies increase recycling, and help establish / ensure a solid waste management system that fosters competitive recycling markets?

- How do you motivate the households to participate in solid waste separation?

- How do you recover recyclable material to produce competitive secondary raw material?

- How do you finance the recovering and disposal activities of local agents?

In the following paragraph, some variables of interest and their historical dynamics from a typical Swiss locality over the last 14 years (1987 – 2001) will be presented. They are crucial in the model development process since they define the reference mode, help clarify the problem statement (Chapter 5.3.1) and model purpose (Chapter 5.3.2) as well as probe the system boundary (Chapter 5.3.3). Subsequently, the question "What caused the given development?" (see Randers 1996) can be addressed (Chapters 5.4 – 5.6.1).

Chart 5.1 shows the development of the municipal budget for solid waste management. There is an increase in cost over time and in some periods there was a deficit. However, there was also an increase in the amount of solid waste during this time. Therefore, this chart gives us no information about the development of costs per kg.
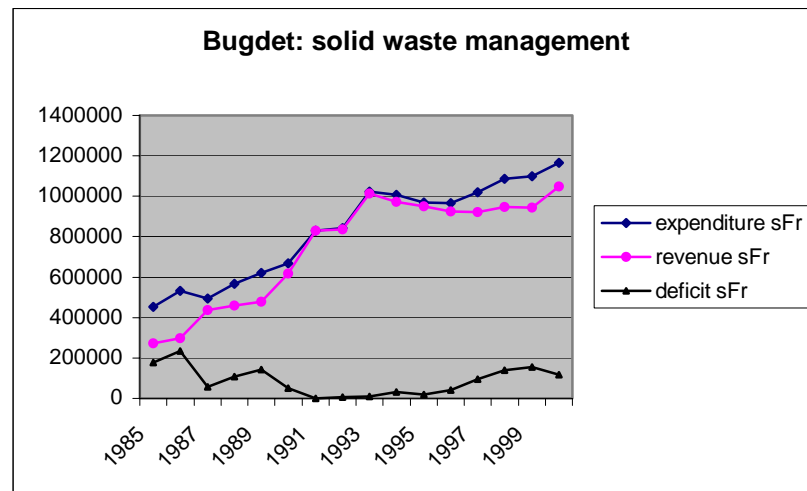
Chart 5.1: Municipal budget development for solid waste management (Einwohnergemeinde Ittigen 1985 - 2001).

In order to slice the problem (see Saeed 1992) and to decompose the growth trend of solid waste generation, the budget of solid waste per capita and per kg is computed (see Chart 5.2).
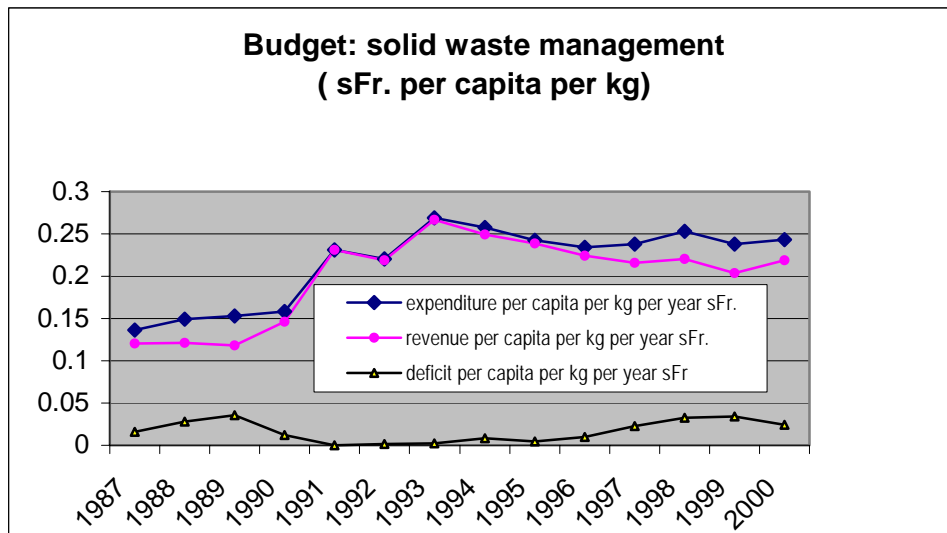
Chart 5.2: Municipal budget development for solid waste management in sFr. per capita, per kg, per year (Einwohnergemeinde Ittigen 1985 - 2001).

According to Chart 5.2 there is an upward trend in the unit cost that peaks in 1994 followed by a slight drop, and then it seems to reach a plateau. However, the revenue continues to fall. There are two periods with a higher deficit (1987 – 1992) and (1996-2001). As the deficit has grown, the local authorities increased the tax for solid waste management and the volume related garbage bag charges (see Table 5.3).

Time period	1973 - 1990	1991 - 1999	2000 - ???
Taxes, per year, according to the size of the apartment / house	24 – 60 CHF.	50 – 110 CHF.	83 – 184 CHF.
Volume related trash-bag charges (35 liter)	None	0.9 CHF	1.80 CHF.

Table 5.3: Changes in taxes and trash-bag charges. (Einwohnergemeinde Ittigen (1973b), (1990b), (2000)).

Citizens not only have to pay money for financing their waste disposal they also have to separate their garbage. This task is growing since they have to sort out their garbage according a growing number of recycling streams as is shown below. Table 5.4 illustrates the development of the different recycling streams. The data of the official federal monitoring system show that in 1987 only five different sorts of material were systematically recovered from solid waste, in 2001 there were nine.

Separated Materials	1987-1991	1992	1993	1994-1997	1998-2001
Organic material	▓	▓	▓	▓	▓
Paper	▓	▓	▓	▓	▓
Glass	▓	▓	▓	▓	▓
Metal	▓	▓	▓	▓	▓
Aluminum	▓	▓	▓		
Pet		▓	▓	▓	▓
Ferrous metal (tins)			▓	▓	▓
Food scraps			▓	▓	▓
Hazardous waste (oil)				▓	▓
Electronic waste					▓
Number of recycling streams	5	6	8	8	9

Table 5.4: Recycling streams separately collected (GSA 1987- 2001).

The following Chart 5.3 clarifies this development overtime and illustrates the changes in the number of recycling streams. Between 1991-93 four additional recycling streams were offered to the citizens. From 1993 to 2001 only one additional recycling stream was introduced.
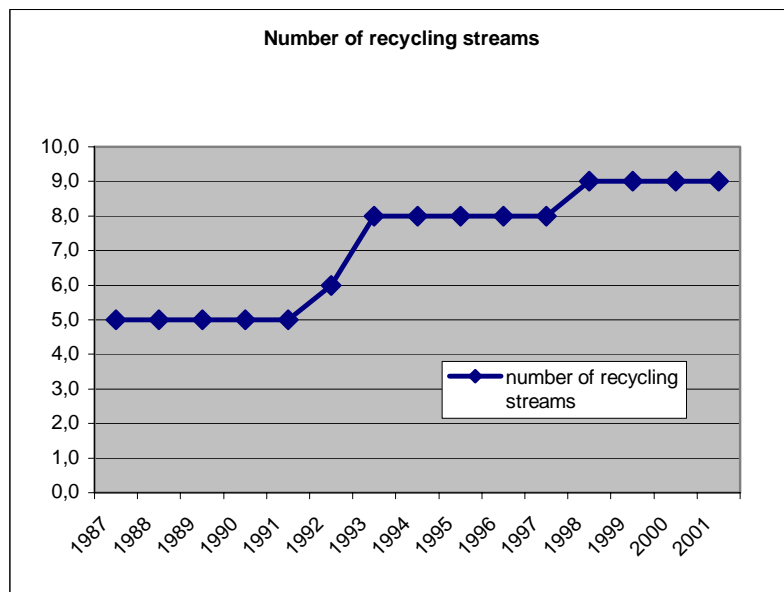
Chart 5.3: Historical development of the number of recycling streams (GSA 1987-2001).

Chart 5.4 portrays the change in the fraction of separated material and the material disposed for burning. The fraction separated for recycling increased from about 30% to 50%.
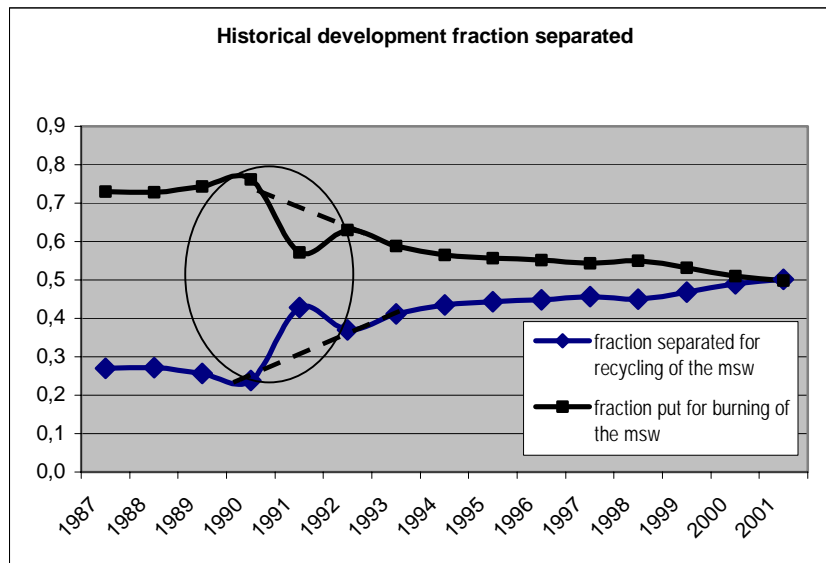
Chart 5.4: Historical development of fraction separated for recycling (GSA 1987-2001).

Between 1990 and 1992 there was a transition phase with a short term dynamic in the fraction of separated waste and the fraction disposed for burning. These dynamics can be ascribed to the implementation of trash bag charges in 1991. As citizens learned that disposal cost would increase, they started to clear out useless material. In 1991 the price incentives had a strong effect on the disposal behavior of the citizens. They probably over invested in separation activities since they tried to avoid disposal cost (over reaction). However, the SD-SWM-model will not address these short-term effects. Nonetheless, it is interesting to see that the 100% increase in the trash bag charges had nearly no behavioral effect in year 2000. A reason for this phenomenon could be that the monetary incentive given in 1991 was high enough to activate the potential capacity of citizens to separate given a constant amount of recyclable material. Stern's concept of limiting conditions would explain this effect at the individual level with diminishing returns of interventions. If the financial incentives demonstrate a clear personal benefit a further increase may be far less effective than other interventions (providing more opportunities, giving better information or other incentives) (see Stern 1999).

In order to explain the long-term dynamics of the reference modes the following dynamic hypothesis is postulated.

Since the performance of citizens' separation behavior was low, the localities gave price incentives in the form of a garbage bag charge. The intended effect was to promote the separation behavior. As a consequence the fraction of separated waste increased and the relative amount of solid waste for burning decreased. The unintended effect was that not only the relative amount of waste disposed for burning decreased, but also the revenue generated from the trash bag charges declined. Therefore, the budget deficit started to increase. A further increase in the price for burnable material had nearly no additional effect on the separation behavior, since the number of recycling streams was held nearly constant.

The citizens had no real legal option to avoid higher costs for disposing of burnable material. As an unintended consequence, the quality of separated material decreased. Citizens started to put burnable material in the recycling streams. However, this effect was only observed and could not be exactly quantified.

The following causal loop diagram shows the postulated main feedback loops that are responsible for the dynamics of the variables of interest. The balancing feedback-loop **"limiting propensity from time cost"** refers to citizens' behavior (Figure 5.3) and the other **"deficits limits investments"** refers to the authorities (Figure 5.4).
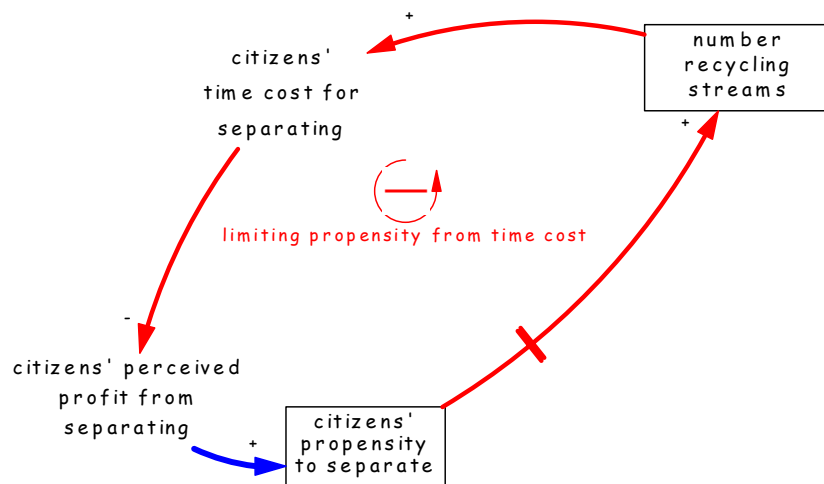
Figure 5.3: Dynamic hypothesis focusing on the loop "time cost limiting propensity to separate" (citizens' choice).

The balancing feedback loop **"limiting propensity from time cost"** postulates that a high propensity to separate would foster (with a delay) the development of further recycling streams. This link represents the theory that a high discipline in separation behavior of citizens would increase the purity of the separated recycling material. As a consequence, the recycled material would become competitive, fostering the development of recycling capacity, and new recycling streams. As the number of streams increases, the time cost to separate increases. This results in both a lower perceived profit and propensity to separate.
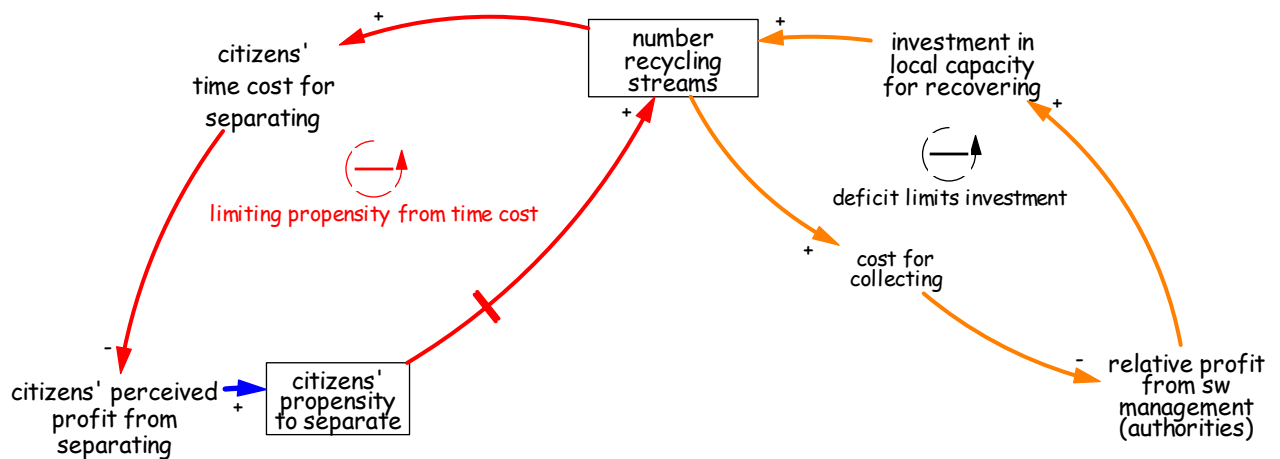
Figure 5.4: Dynamic hypothesis focusing on the loop "deficits limits investment" (choice of the authorities).

The balancing feedback loop **"deficit limits investment"** describes the economic concerns of the localities. As long as the price for disposing the separated material is lower than for burnable material, there is a relative profit in the local recycling program. As the number of recycling streams increases, the operating cost rises for collecting the various separated materials. Therefore, the relative profit from the recycling program decreases and the willingness to invest in local capacity decreases as well.

These two balancing loops indicate that there will be an upper limit in the number of recycling streams, due to limited local capacities.

Figure 5.5 captures the pricing structure in Swiss localities that creates a reinforcing feedback loop **"propensity to separate increases deficit"**. This loop describes the unintended effect of a growing deficit between the revenue and expenditure for SWM-services in the period from 1996 – 2000, (see also Chart 5.2). The price incentives given by the trash bag charges increased the propensity to separate. As a consequence, the amount of material disposed for burning decreased relative to the amount of separated material, resulting in lower revenue from burnable material. Therefore, not only the relative but also the overall profit decreases (respectively the deficit increases). Consequently, the authorities raised the price for burnable waste in year 2000. This reinforcing loop indicates that this pricing structure will not ensure a sound solid waste management system.
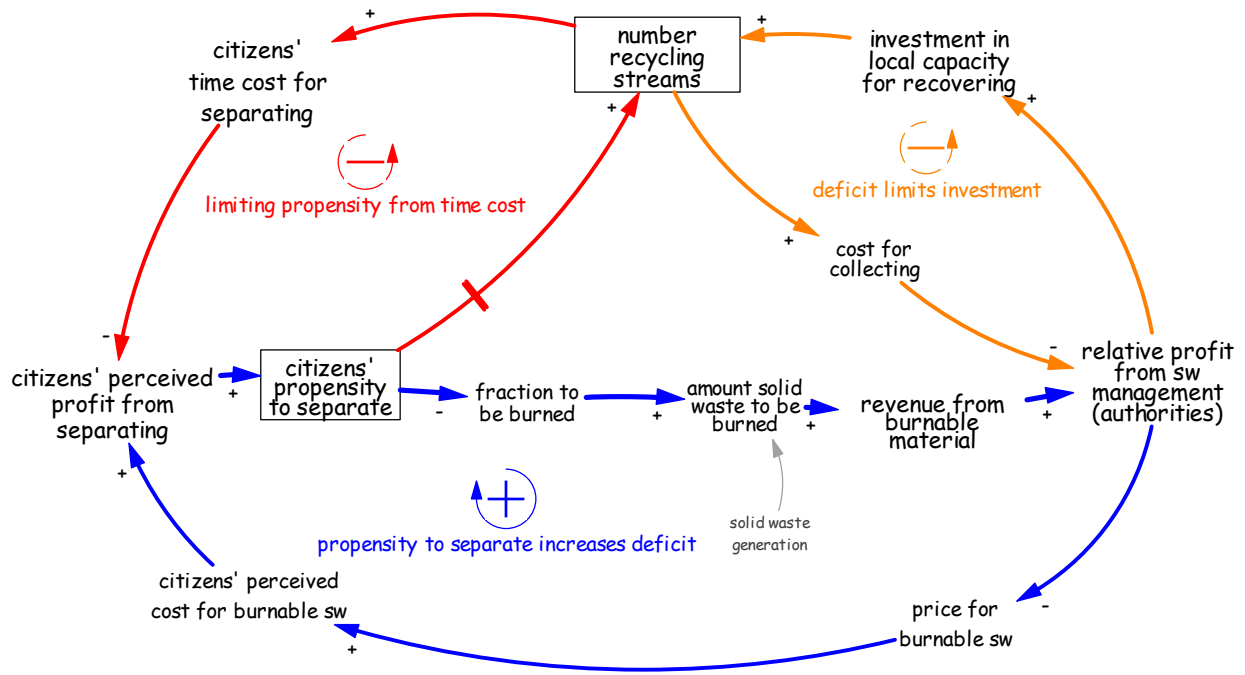
Figure 5.5: Dynamic hypothesis focusing on the loop "propensity to separate increases deficit".

The next reinforcing loop **"policy resistance"** (Figure 5.6) explains, how a further unintended effect sabotages the local recycling program. Due to price incentives the citizens perceive a high profit from separating (see the lower feedback loop) and their propensity to separate increases. Since only a limited fraction of solid waste is recyclable, the citizens are tempted to put burnable material into the recycling streams in order to avoid disposal costs. Therefore, the impurity in the separated material increases. As a consequence, the recycling industry is not going to accept these materials or will charge higher prices. This increases the operating cost of the localities and decreases the relative profit and also the willingness to invest in local capacity for separating. Therefore, the number of recycling streams could decrease. Given a high propensity to separate, citizens continue to put burnable waste into the recycling streams.
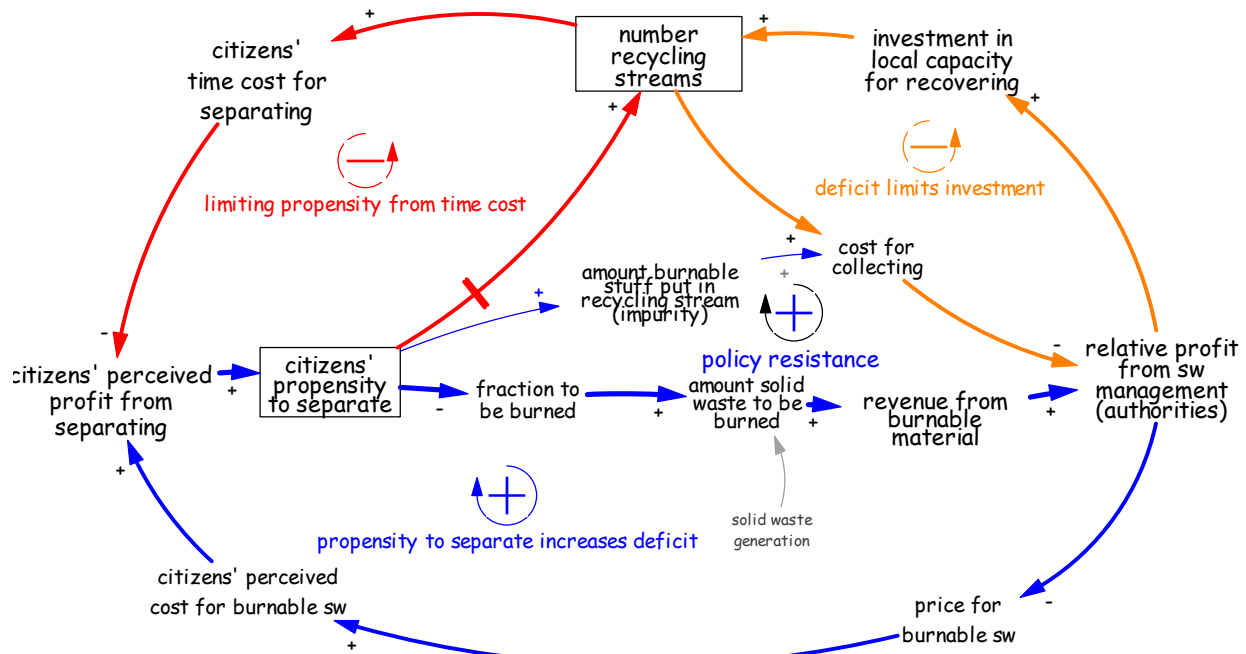
Figure 5.6: Dynamic hypothesis focusing on the loop "policy resistance".

The outline of the problem and the dynamic hypothesis illustrated in the causal loop diagrams suggest that the number of recycling streams is an important stock at the local level. The following causal loop diagram **"trap / chance recycling market"** (Figure 5.7) gives a reason, why the number of recycling streams is also a critical factor for development of recycling markets. This feedback structure partly describes the dynamics of the invisible hand [52].

A higher number of recycling streams decrease the cost for recycling, since the recycling industry gets a better quality of collected material. Hence, it has to invest less in sorting processes. Lower production cost of secondary raw material increases the profit and reduces the relative price of recycled raw material. Therefore, the demand for recycled raw material will increase. Furthermore, over time the supply and the variety of recyclable material in products will increase. As a result of a successful recycling market, not only the willingness to invest in higher capacity increases but also the readiness of new recycling technologies to enter the recycling-market increases. Therefore, the number of recycling streams grows. If the citizens will separate the recyclable material according to the different recycling streams, the recycling industry will face lower recycling cost. In this scenario the reinforcing feedback loop will foster a growth in the recycling market. Otherwise, higher processing cost from impure recycling material will shut down the recycling market. These scenarios will be analyzed in the model.

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[52] For the complete feedback structure of markets, see Sterman (2000:170).

Results of some pilot-experiments and studies about expanded recycling initiatives for plastic in different Swiss localities give empirical evidence of the stated dynamic hypothesis (BUWAL 2001).
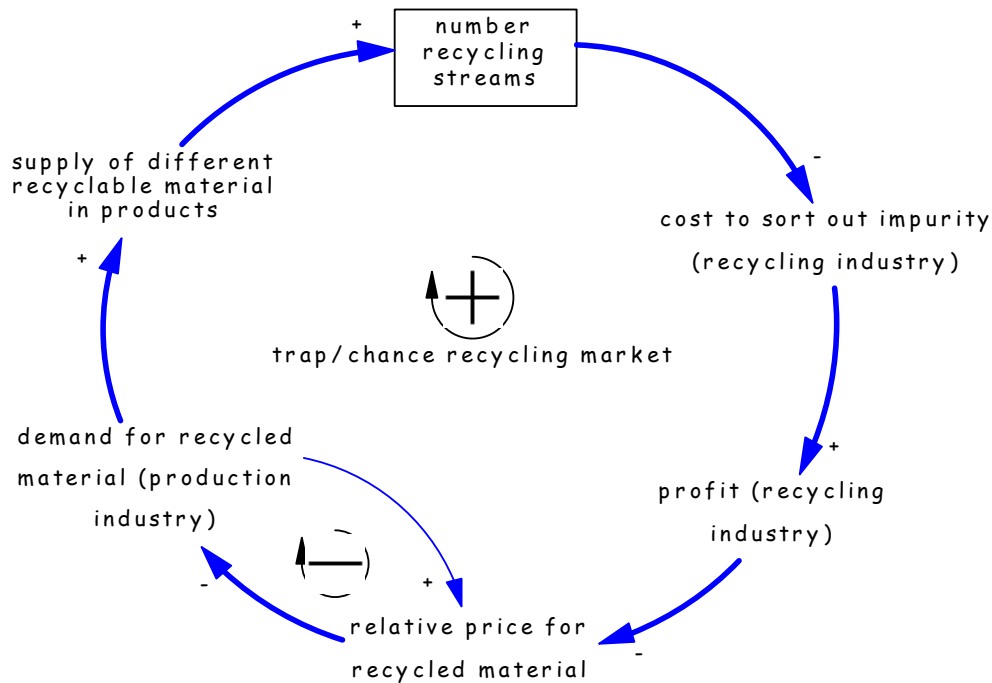
Figure 5.7: Dynamic hypothesis focusing on the loop "trap/chance for the recycling market".

Effects of prepaid disposal charges

With the SD-SWM-model not only the given development will be addressed, but also the effect of further policy-strategies, such as prepaid taxes. The model will be designed to provide insights on the question: what are the likely effects of other strategies such as prepaid disposal charges on a growing number of products?

Prepaid disposal charges have an important feature. For the consumer this is a hidden price. Therefore, the collecting service system will have a feedback structure of non-price mediated resource allocation (see Sterman 2000). This structure is depicted in Figure 5.8 adopted to recycling dynamics.
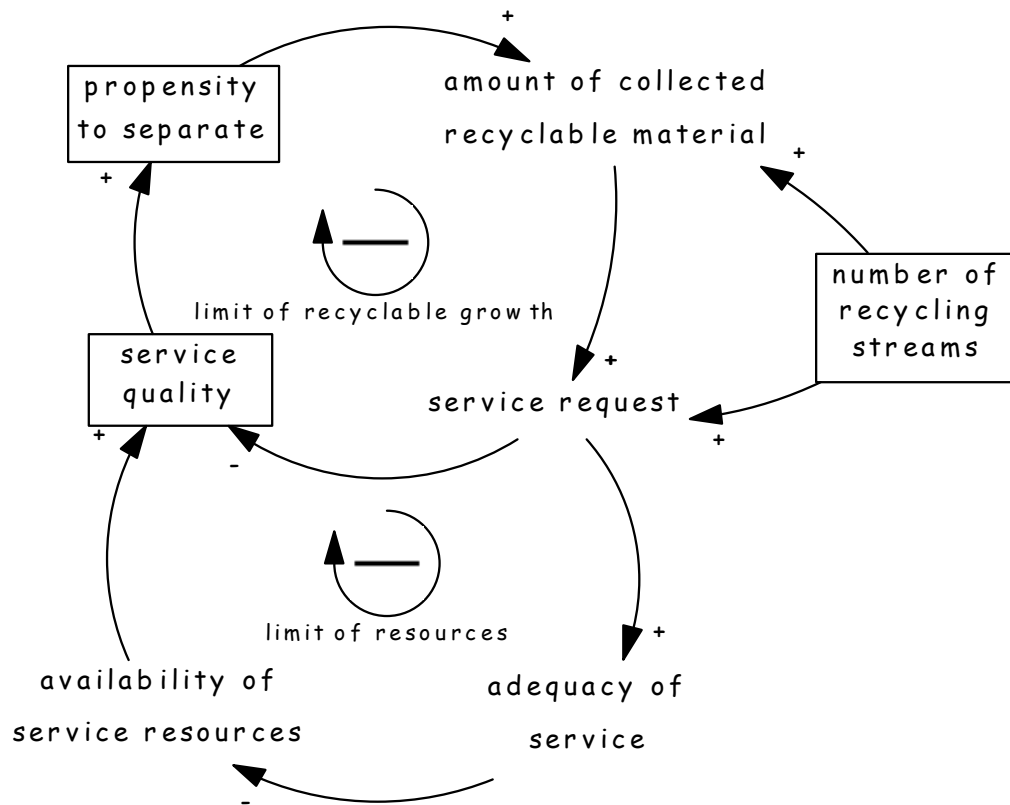
Figure 5.8: Feedback structure of the non-price mediated resource allocation system (adapted from Sterman 2000:172).

A higher service quality in the collecting centers stimulates the propensity to separate. Citizens will bring back a higher amount of different recyclable material. A higher amount of collected recyclable material erodes the service quality as the crowding increases. This dynamic represents the balancing feedback loop **"limit of recyclable growth"**. Accordingly the service quality will limit the amount of collected recyclable material. The second balancing feedback loop **"limit of resources"** shows that a higher service request increases the need for adequate services. The increased adequacy of service will demand a better infrastructure, which would elevate cost. As a consequence, the availability of service resources will be diminished, resulting in lower service quality.

The two balancing loops indicate that a prepaid disposal charge can foster the separation behavior of citizens only to a certain limit. Once the propensity to separate tends to decrease, the fraction separated for recycling will stay constant on a certain equilibrium level, even when perceived market forces tends to boost the number of recycling streams further.

Chart 5.5 represents the hypothesized reference mode that takes into account the underlying balancing feedback structure explained in Figure 5.8. Due to the balancing feedback loops the fraction separated for recycling will reach an equilibrium position while the maximal acceptable number of recycling streams for citizens will be reached. Due to information delays in the market system the number of recycling streams will increase further resulting in an overshoot in the number of recycling streams.
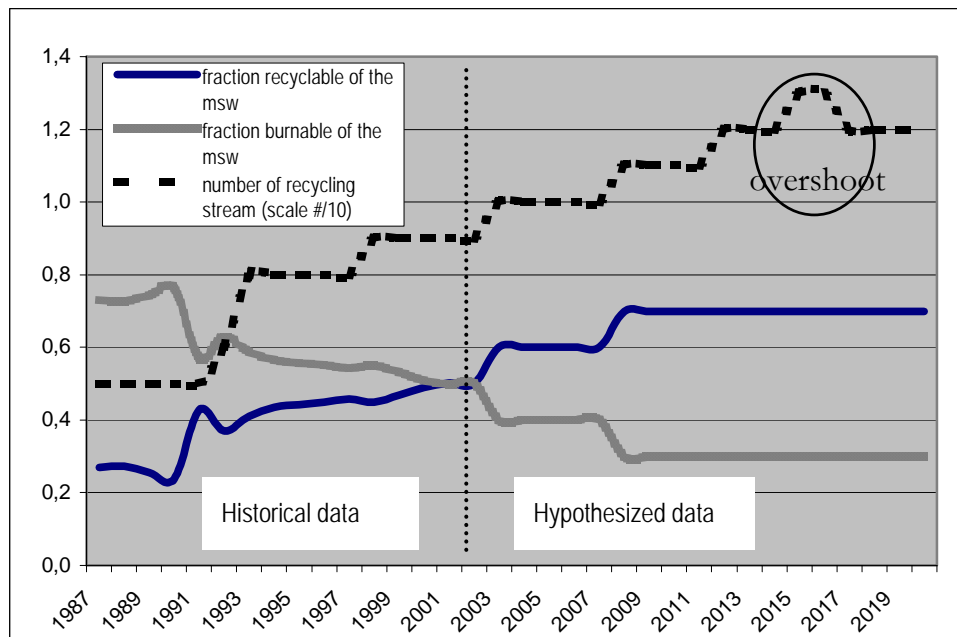
Chart 5.5: Hypothesized development of fraction separated for recycling and number of recycling streams.

For the time frame of this study a steady increase in the overall amount of waste (including both burnable and recyclable waste) is hypothesized, which could even be exponential. This assumption reflects the observation that solid waste generation is highly correlated with economic growth[53]. The scenario of economic growth shows the externally driven behavior pattern. This component of the behavior pattern is modeled in a smaller subsystem that can be switched off. Subsequently, the discussed developments in the SD-SWM-model can be analyzed either with or without economic growth – scenarios. This helps to partition the messy problem in the solid waste management into macro-economically driven developments and into policy-incentive driven developments (see Saeed (1992) in Richardson (1996)). One additional challenge of this work would be, to analyze if the macro-economically driven development could be influenced by local policy interventions. Under which condition could a growing green consumerism result in solid waste avoiding behavior (see also Joos, Carabias et al. 2002)[54]?

5.3.2 Purpose of modeling

The model is designed to create a computer based learning environment or a micro world for local policymakers to play with their knowledge of the solid waste system and to debate policy and strategy change (see Morecroft 1988). It can be used as a communication tool in

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[53] http://www.umwelt-schweiz.ch/buwal/eng/medien/umweltbericht/druck/index.html (Swiss Agency for the Environment, Forest and Landscape)

[54] http://www.IP-Waste.unibe.ch/public/Abschlussband/inhaltsverzeichnis.html

order to enhance a debate between the different agents about organizational structures in the area of solid waste management (see Schwaninger 1997). Finally, it adds to the scientific discussion about long-term dynamics between citizen choice and preferences and public policy initiatives. Indeed, it may shed some light on the role of local authorities as a key player in creating and structuring markets (see Chapter 3.5).

To be more concrete, the following objectives should be met: Firstly, the model helps discover the underlying causes of changes in the *<fraction separated>* and the quality of the separated material. Secondly, the model is designed to uncover and clarify possible side effects of changes in the price structure and of prepaid disposal charges. Thirdly, the model helps local authorities dealing with mandates from the federal government and implementing sound solid waste management policies.

In sum, the sub-goals and research questions outlined in Chapter 2.1.2 should be addressed with the help of the model.

5.3.3   The overall SD-SWM-model structure

Before entering in the discussion of the detailed model structure a brief overview of the model is given. It gives the big picture justifying the chosen aggregation level and shows the different model parts and their relationships as well as basic feedback loops.

In order to analyze long-term effects of different local policy interventions a time horizon from 1987 to 2020 was chosen. For the time period 1987 to 2001 there is data available (see reference modes) revealing historical patterns of behavior. The time span of two decades from 2002 to 2020 allows experimenting with further policy options and strategies and analyzing their behavioral impact. The sectors in the model are seen from a specific distance in order to see the internal structure, social pressures, market forces, and important decision points. A balance between a microscopic view that is too psychological and a telescopic view that captures an economic perspective that is too aggregated is aimed for (see Forrester 1961, Richardson 1991). Therefore, in the model the different recyclable materials will be aggregated to one flow. However, the model is designed to focus on the number of different recycling streams and the effects of a change in the number.

The overall model structure is described below and illustrated in Figure 5.9: The SD-SWM-model includes the following sectors that are visualized in the Sector Diagram of the extended SD-SWM-model. The main sector is the local separation sector that is disaggregated in the following sub sectors: household waste separation sector, household decision sector and local policy sector. These sectors include endogenously operating dynamics deemed important to address the solid waste management problems and to conduct policy analysis.

The household waste separation sector includes:

- The different flows and qualities of the burnable and recyclable waste that result from separation activities of different groups of citizens.

- The initial amounts of different waste qualities, and recyclable and burnable material will be given exogenously but will be modified by behavioral effects.

- The habits of different groups of people to dispose their waste and factors that lead to changes in habits (i.e. changes in relative prices and the number of recycling streams).

The household decision sector will describe:

- What factors influence the decision of people to become willing / unwilling to separate the recyclable material?

- What influences the willingness to spend time or money on waste separation activities?

The local policy sector / solid waste management sector includes:

- The development of the garbage bag charge and the municipal budget for solid waste management under different policy options.

- Capacity building processes and the effect of a backlog of separated waste.

The income per capita and the population are given exogenously. Furthermore, basic structures of the recycling sector, the supply sector and the incineration sector are designed at a higher aggregation level representing the development of recycling markets. However, those sectors are only presented as preliminary qualitative concept models, that could be developed further in follow up studies. In these sectors capacities, prices and changes in number of recycling streams could be computed. This information would be transmitted into the local separation sector. Some aggregated information about the impact on the environment of incineration and recycling activities and of the exploitation of raw material from the supply sector would influence the household decision sector. Some time delays due to unavailable and delayed information will occur at different decision points such as in capacity adjustment processes influencing the system behavior (see Chung 1992).
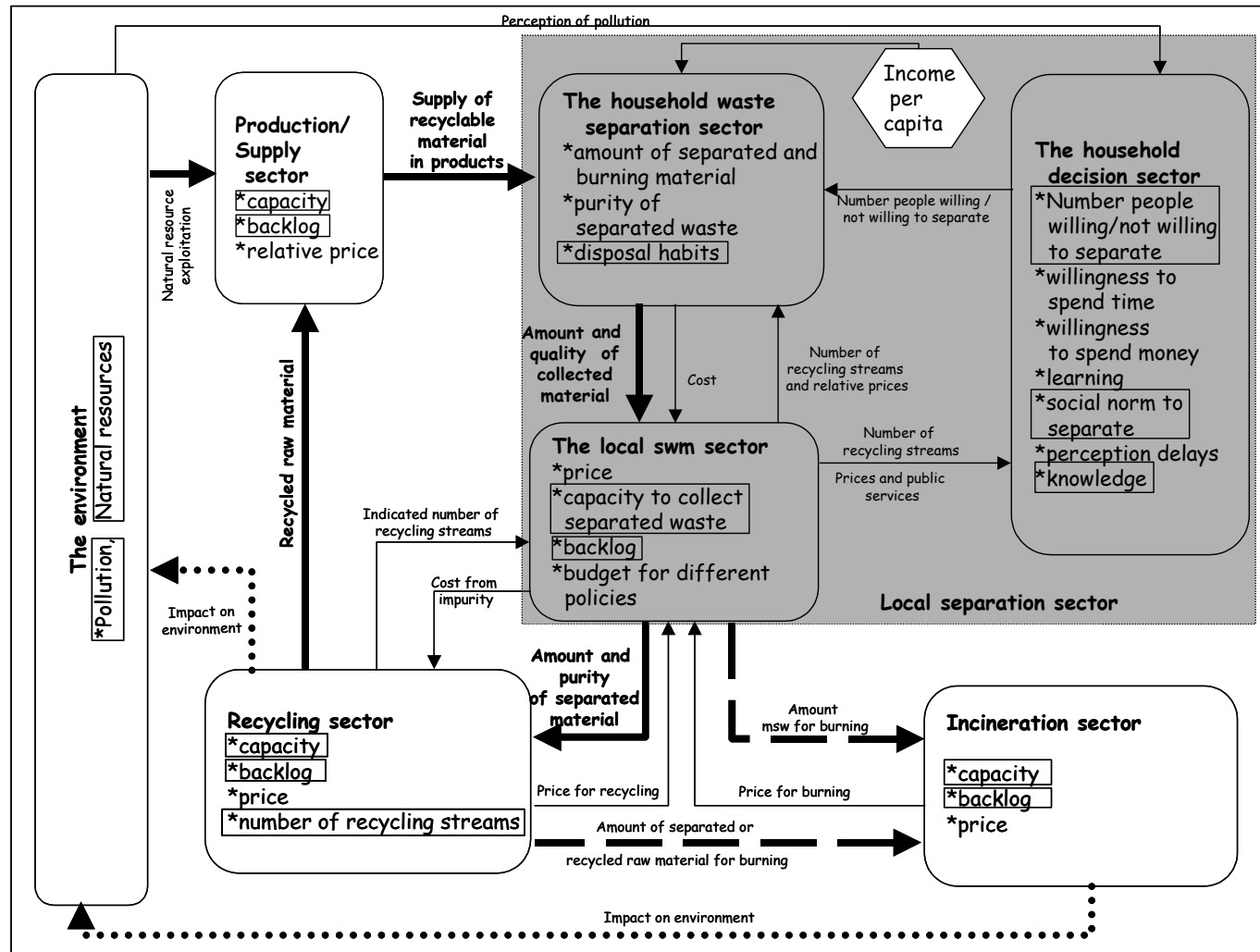
Figure 5.9: Sector Diagram of the extended SD-SWM-model

5.4   The sectors of the SD-SWM - model

This section first describes the core model parts in depth. Then it explains how those model parts could be complemented by further model-sectors in order to capture interactions of market forces and capital building processes endogenously. Since the concept of propensity – the propensity of citizens to separate - seems to be crucial for the success of recycling programs, it will be modeled explicitly. Therefore, a special weight is put on the formulation of the decision process guiding citizens' behavior to separate. In the feedback perspective on human behavior and public policy (Kaufmann-Hayoz, Bättig et al. 2001), contextual and personal factors in a decision making process are emphasized. Therefore, in the SD-SWM-model, interactions between contextual and personal factors will be addressed. Hidden attitudinal stocks in the system can create adaptation delays leading to unexpected system behavior and unintended consequences. Elements of the personal structure will be represented in the household decision and the household separation sector.

5.4.1   Designing propensity to separate: The household decision sector

The preceding theoretical discussions suggest that citizens' disposal behavior may be described partly as routine behavior and partly as a planned behavior. In Forrester's terminology this would be called an informal policy. "… But most guiding policies are informal, although fully as influential. Informal policy results from habit, conformity, social pressure, ingrained concepts of goals, awareness of power centers within the organization, and personal interest" (Forrester 1994:58). This assumption suggests that people decide once whether to separate or not. Once they have made this decision, they set a new routine, resulting in new separating habits (see e.g. Dahlstrand and Biel 1997). This implies that there are two main groups of citizens: a group of people willing to separate and a group of people not willing to separate. However, in each population we can distinguish sub groups that are transients (see Figure 5.10):

- In the group of people willing to separate there are some inexperienced people – they will show a lower separation performance than the experienced ones. But as they learn to separate they will move into the stock *<ep willing to separate>*. The *<time to learn>* determines how long this takes. In the model the *<time to learn>* is represented by the variable *<time on moving from iep to ep>*. It is a function of the *<average amount appropriately separated by nwiep>* and the *<normal amount appropriately separated wep>*[55].

- In the group "people not willing to separate" there are experienced people that got disappointed from separation consequences. The *<experienced people not willing to separate>* will move into the stock *<ep not willing to separate>* as they will forget, they are changing their separation behavior and set up a simpler routine behavior. The *<average time to forget>* calculates when these people will move on.

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[55] Acronyms: ep – experienced people; iep – inexperienced people, wep – willing experienced people, nwiep - not willing inexperienced people
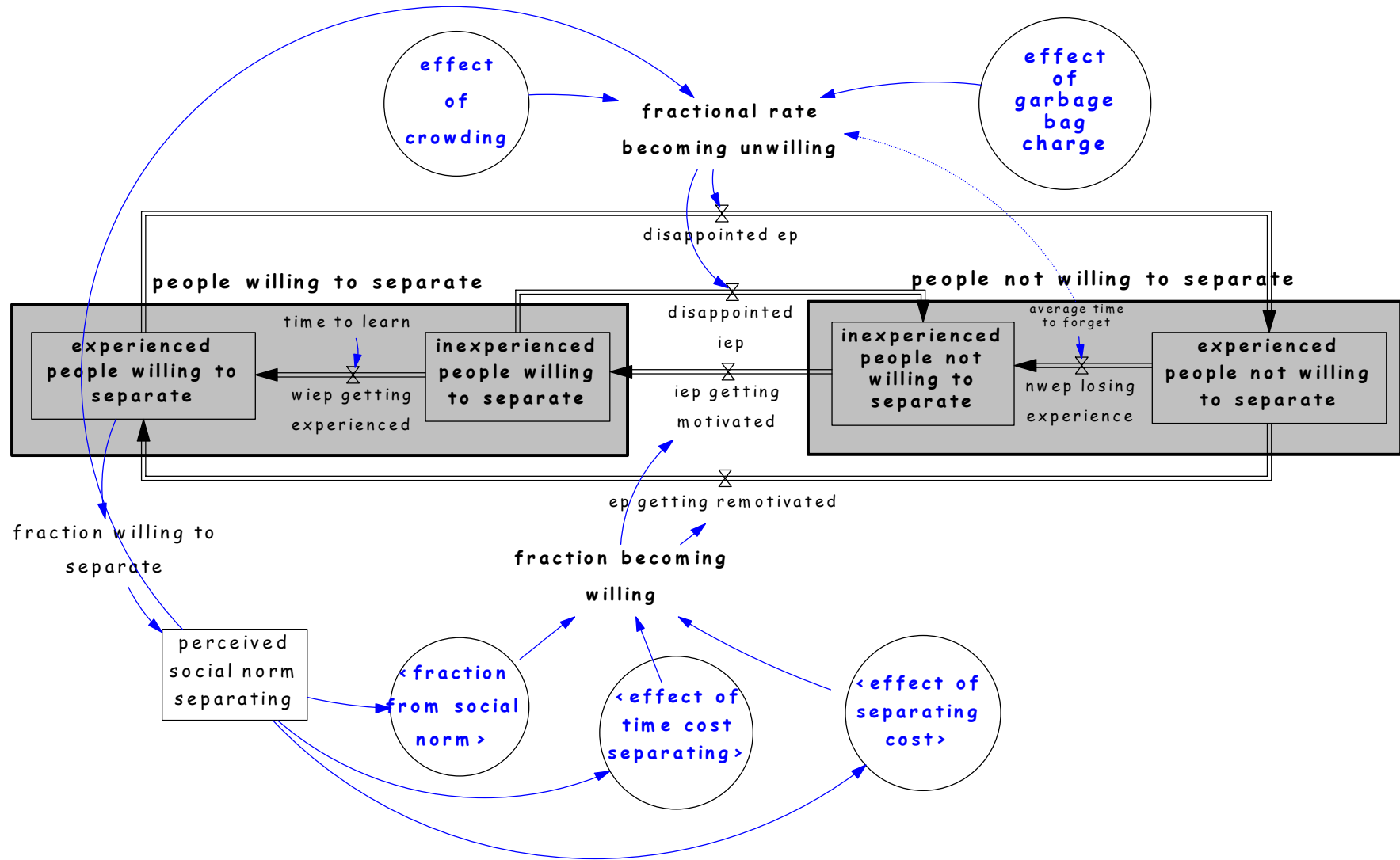
Figure 5.10: Changes in citizen's willingness to separate (ep: experienced people, iep: inexperienced people, wiep: willing inexperienced people, nwep: not willing experienced people)

The flow between the two groups of "people willing to separate" and "not willing to separate" is an important decision point in the system. Therefore, its decision rule determining the rate has to be precisely formulated (Forrester 1961, 1994, Sterman 2000). The goal would be to formulate the decision rules with sufficient accuracy in order to gain insight into how people respond to different conditions, pressures and policy interventions. Following Forrester (1994) the aim is not to mimic a process of planned behavior. He suggests a process of seeing governing policies rather than individual decisions.

The decision to separate is influenced by *<perceived social norm separating>*, by *<acceptable time for separating>,* and by *<acceptable separating cost per year>*. The decision to become unwilling is influenced by alternative costs such as *<acceptable time burning>* and *<acceptable unit cost for burning>* and *<perceived social norm burning>*. In a further advanced version of the model, factors such as "perceived policy effectiveness" and "knowledge" could be included in the decision function. The information about the decision cues (e.g. "time cost", "real cost", later on the "perceived policy effectiveness") are partly given exogenously or would be computed endogenously in an enlarged model including further model sectors.

Some psychological assumptions

The decision rule applied is based on some psychologically grounded assumptions that social norms have an influence on action choices (e.g. Latané 1981, Cialdini, Reno et al. 1990, Hopper and Carl-Niesen 1991, Reno, Cialdini et al. 1993, Mosler 2000, Mosler, Gutscher et al. 1996, Black, Stern et al. 1985). In the following paragraph exemplarily, some assumed non-linear relationship and decision rules guiding the rate *<iep getting motivated>* and *<ep getting remotivated>* will be made explicit and explained.

Social norm

The *<perceived social norm separating>* is a function of the *<fraction willing to separate>*. An increase in the *<fraction willing to separate>* in the municipality, will generate a stronger norm to separate, resulting in a higher number of people willing to separate. In the decision function this idea is represented in a non-linear function (see Chart 5.6). Given the obvious disposal - or environmental problems it is reasonable to assume that a
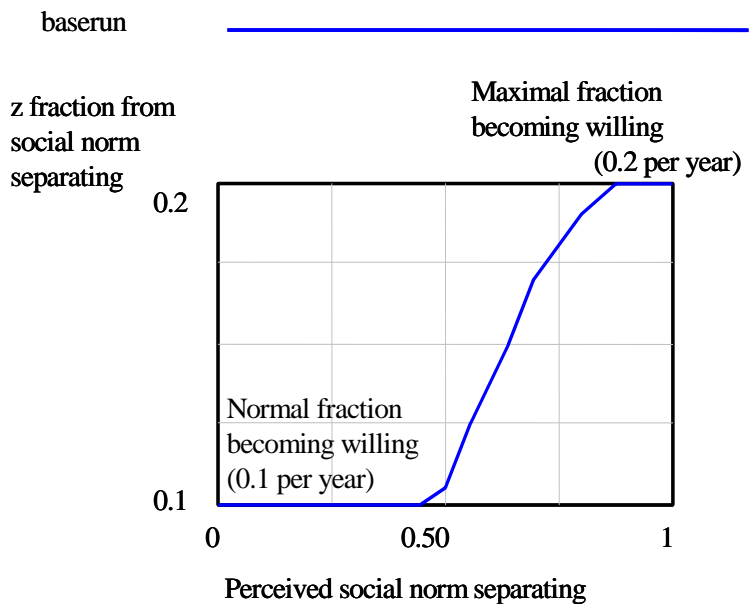
Chart 5.6: Lookup-function <z fraction from social norm separating>.

small normal fraction of people will become willing to separate even when they perceive no social norm or only a minimal to do so.

The normal fraction people becoming willing from *<perceived social norm separating>* is assumed to be 10% per year, resulting in a doubling time of 6.93 years[56] reflecting the maximal diffusion delay (ceteris paribus). The fraction will increase when nearly 50% of the population generates a *<perceived social norm separating>*. When nearly the entire population is willing, a "maximal fraction" (20% per year) will be reached. This value computes the minimal diffusion delay in the population (doubling time 3,5 years).

The s-shape relationship reflects the assumption that people that are easy to convince will become willing to separate first (early adopters) and those that are more persisting will join later on.

Acceptable time to separate

The "willingness to spend time for separating" is a function of the *<perceived social norm separating>*.

It is assumed that people have a *<maximal acceptable separating time>,* that they are willing to invest in separating activities. However, this time would be lower, if the *<perceived social norm separating>* is low. Chart 5.7 shows this relationship. The non-linear lookup function discounts the *<maximal acceptable separating time>* (y-axis) when the *<perceived social norm separating>* declines (x-axis) and computes the actual *<acceptable time for separating>*.
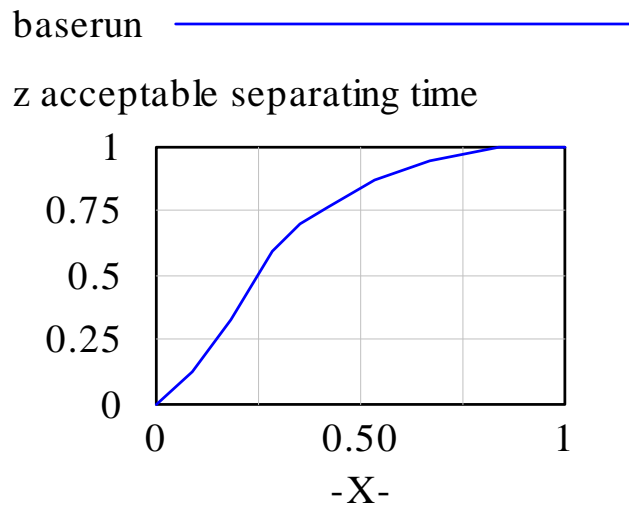
Chart 5.7: Lookup-function <z acceptable separating time>, (X-axis: <perceived social norm separating>, Y-axis: discount in percent of the maximal acceptable time resulting in <acceptable time for separating>).

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[56] Doubling time = ln(2)/fraction "becoming willing" (see Sterman, 2000:269)

Effect of time cost separating

It is assumed that time cost may affect the normal diffusion process induced by the social norm.

z effect of time cost separating

The lookup function or also called graphical converter <*z effect of time cost separating*> computes the <*effect of the time cost separating*> on the diffusion process (see Chart 5.8). The <*effect of time cost separating*> on the diffusion process is one – meaning that it has no influence -; when <*time spent for separating*> = <*acceptable time for separating*>; the graphical function

Chart 5.8: Lookup-function <z effect of time cost separating>, (x-axis).

passes the reference point (1,1). If the <*time spent for separating*> is very low the diffusion process will be accelerated to a maximal value of 1.5. If the <*time spent for separating*> (TSS) is twice as high as the <*acceptable time for separating*> (ATS) the diffusion process will be stopped.

Acceptable separating cost

The variable <*acceptable separating cost per year*> is based on the same assumption as the formulation of <*acceptable time for separating*>. The maximal recycling cost that people are willing to pay will be discounted, as the <*perceived social norm separating*> will decrease.

Effect of separating cost

The graphical converter <*z effect of separation cost*> would calculate the effect of some prices for separating services in a similar way as the converter for <*z effect of time cost separating*> described above.

Decision rules

The <*fraction becoming unwilling*> is formulated in a similar way as the <*fraction becoming willing*>, but the effect of opportunity cost <*effect of time cost burning*> and <*effect of burning cost*>, as well as the <*fract becoming unwilling from social norm burning*> will determine the rate. All the rates are determined by a multiplicative formulation, since any extreme value in each of them can dominate the other effects as well as one effect can also reinforce another. The concrete formulation for the <*fraction becoming willing*> is:

<Fraction becoming willing> = <fract becoming willing f social norm separating> * <effect of time cost separating> * <effect of separating cost>

In addition, it is assumed that the two stocks *<ep willing to separate>* and *<iep not willing to separate>* will never get to zero. There will always be a fraction that will not change its behavior. This design would represent people with strong beliefs, people that just do not see any profit, or that are over occupied by the separating task.

5.4.2   The household waste separation sector

In the household waste separation sector, four different qualities of waste will be computed. The waste generated consists of recyclable material (A-waste) and non-recyclable material (B-waste). Therefore, the people have four different action choices to dispose the waste (see Figure 5.11).

A: The recyclable material can be appropriately separated (A1) or can be disposed for burning (A2).

B: The non-recyclable material can be disposed for burning (B1) or it can be inappropriately separated (B2) (generating impure and more expensive recycling material). Figure XY illustrates how the different qualities of waste are computed.
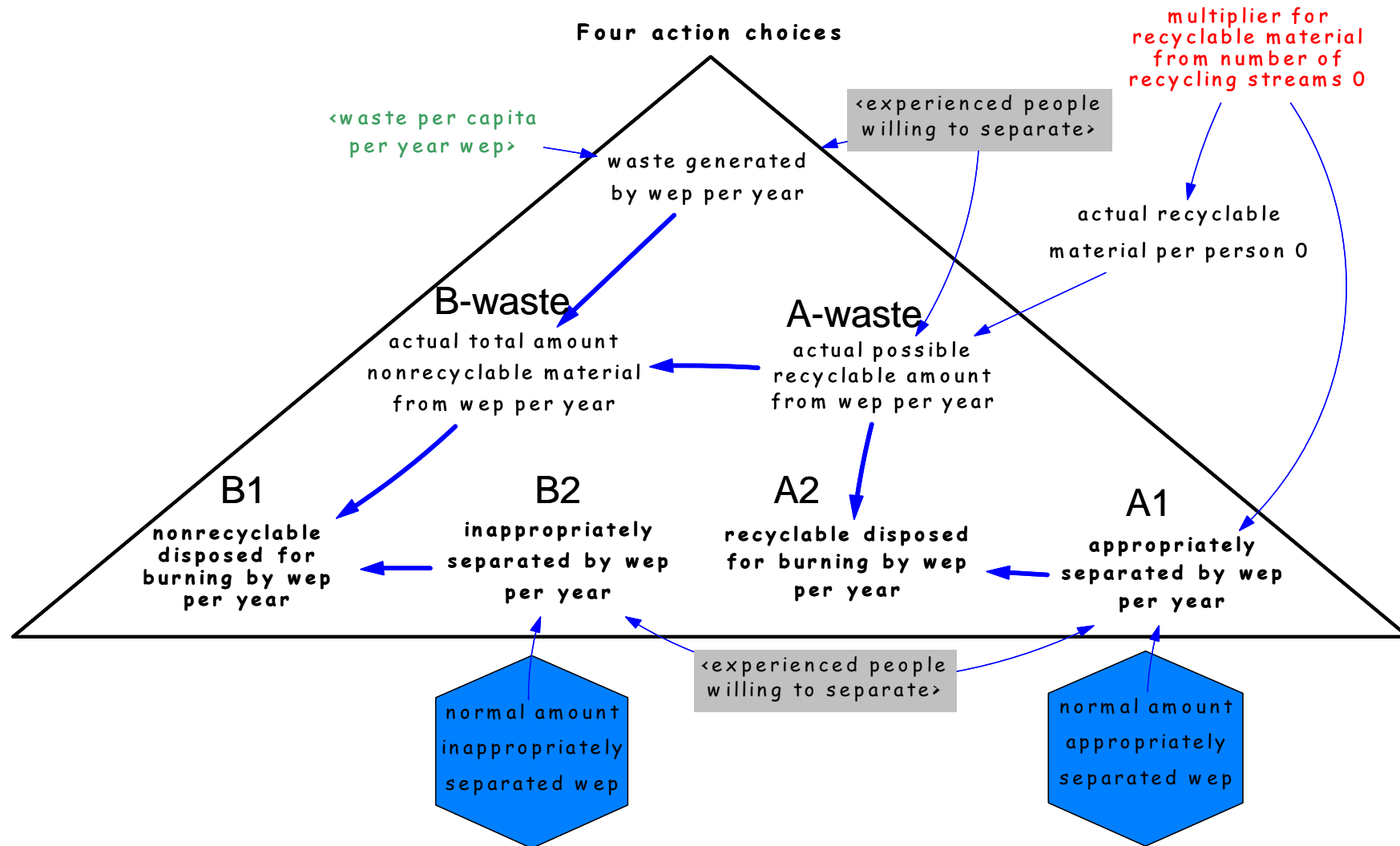
Figure 5.11: Action choices for disposing of the waste (wep: willing experienced people): The behavioral variables (indicated by diamonds) represent disposal habits. They measure the normal amount inappropriately separated (B2-waste) and the normal amount appropriately separated (A1-waste). They also determine both counterparts: the amount recyclable disposed for burning (A2-waste) and the non-recyclable disposed for burning. (B1-waste).

The per capita waste generation for all four groups is assumed to be the same over the years and will be held constant: 339 kg/person/year (based on real data 1987, Table 5.5).

Waste per capita	339,0 kg/person/year
Waste put for incineration	247,6 kg/person/year
Waste separated	91,3 kg/person/year

Table 5.5: Real data waste generation and separation in 1987.

The real data pertaining to different waste qualities "waste put for incineration" and "waste separated" reflect an average system performance and a mixture of A1 and B2, respectively A2 and B1 waste qualities. However, in the model it is assumed that the four different groups of people have different disposal habits, generating different amounts of the four waste qualities. Chart 5.9 illustrates the assumed waste composition of the four groups of people. The compositions are calibrated, based on data of generated waste per capita in 1987.
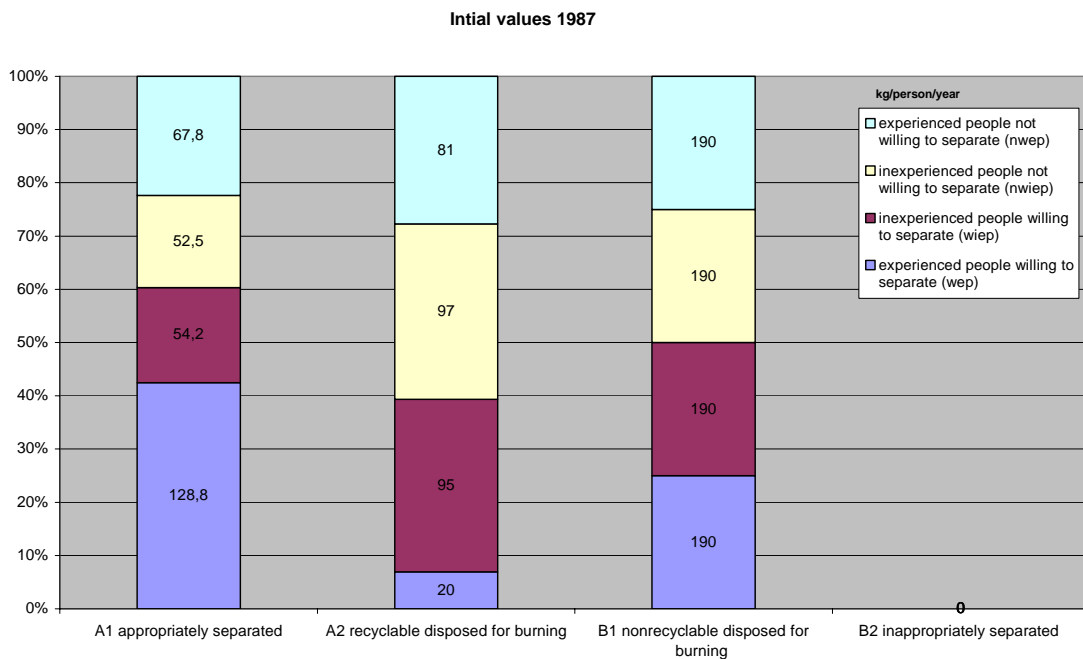
Intial values 1987

Chart 5.9: Waste composition of the four groups of people (Initial values assumed for 1987).

Given the disposal habits of the four groups, their contribution to the four qualities can be shown. The *inexperienced people not willing to separate* start to produce 100% of the inappropriately separated waste (see Chart 5.10).

Values baserun 1992
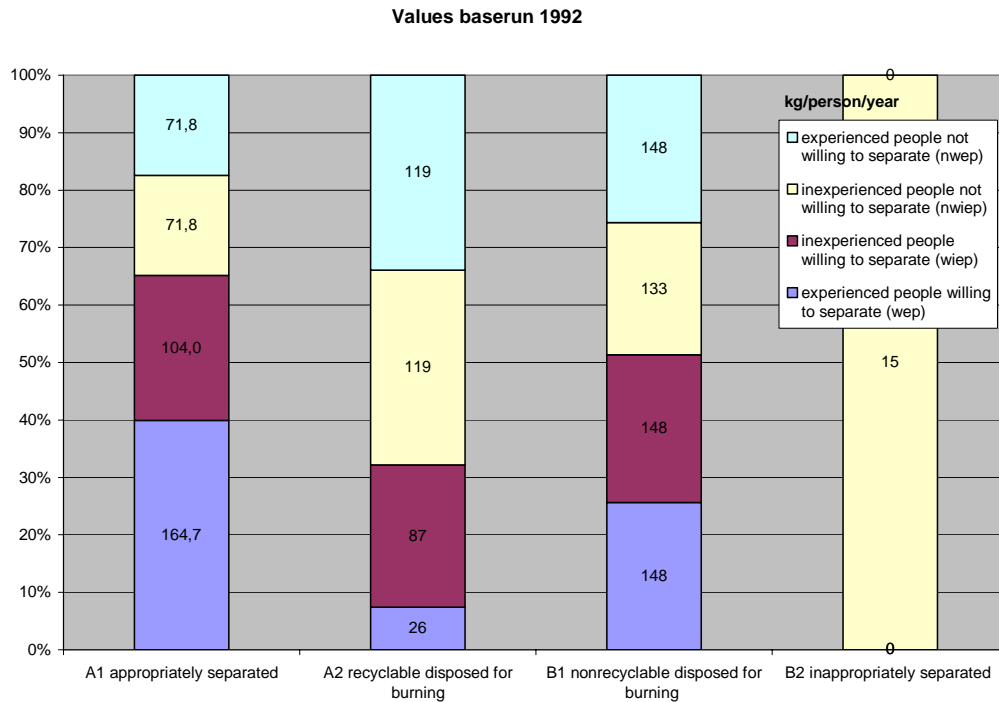
Chart 5.10: Contribution of the four groups to the different qualities of waste (model data 1992, inertia policy).

The different amounts of each group and quality are added together and the *<fraction separated>* can be computed (Table 5.6). The model is calibrated to the real data in 1987.

Model output 1987	Initial amount of waste
Total amount solid waste	3 628 M kg/year
Total amount disposed for burning	2 631 M kg/year
Total amount separated	997 M kg/year

Table 5.6: Model output 1987 calibrated to the real data 1987

As the people move from one group to the other the total amount of separated material will change. The disposal habits of the group *<iep not willing to separate>* are influenced by the *<relative price burning to separating>*. The separation habits of the *<ep willing to separate>* are influenced by changes in the *<effective nr recycling streams>*.

5.4.3 The local policy sector

The local policy sector includes two basic structures. Firstly, a simple budget structure with a price building policy determining the garbage bag charge and secondly, a simple capacity building structure for collecting points under a regime of prepaid disposal tax for recyclable material. These structures capture important feedback loops between different financing alternatives of solid waste management (garbage bag charge, prepaid tax or prices for separated material) and the separation behavior of the people. Specifically, they also represent the *non price mediated resource allocation system* (see Figure 5.8) and the two reinforcing loop **"propensity to separate increases deficit"** and the **"policy resistance"-**loop depicted in Figure 5.6. With this structure the model boundary includes all the important

feedback that were detected in the proposed dynamic hypothesis. Furthermore, it is the last important structure in order to address the problem statement endogenous to the model.

Policy structure: Garbage bag charge

In this policy structure the <*garbage bag charge*> is computed endogenously. Its adjustment is controlled by numerous feedback loops. The basic underlying decision policy is a goal seeking decision-rule leading to a zero deficit budget. The following Figure 5.12 emphasizes the three main feedback loops in a simplified model structure. In the case of increasing cost of solid waste management the two reinforcing loops – **"less burning increases price"** and **"more separation increases cost"** - lead to a steady increase in the <*garbage bag charge*> where as the balancing loop **"less burning reduces cost"** would limit the growth. But since the pool of people that could become "willing to separate" is limited the growth in the <*garbage bag charge*> will be restricted by the overall number of <*people separating*>, as well.
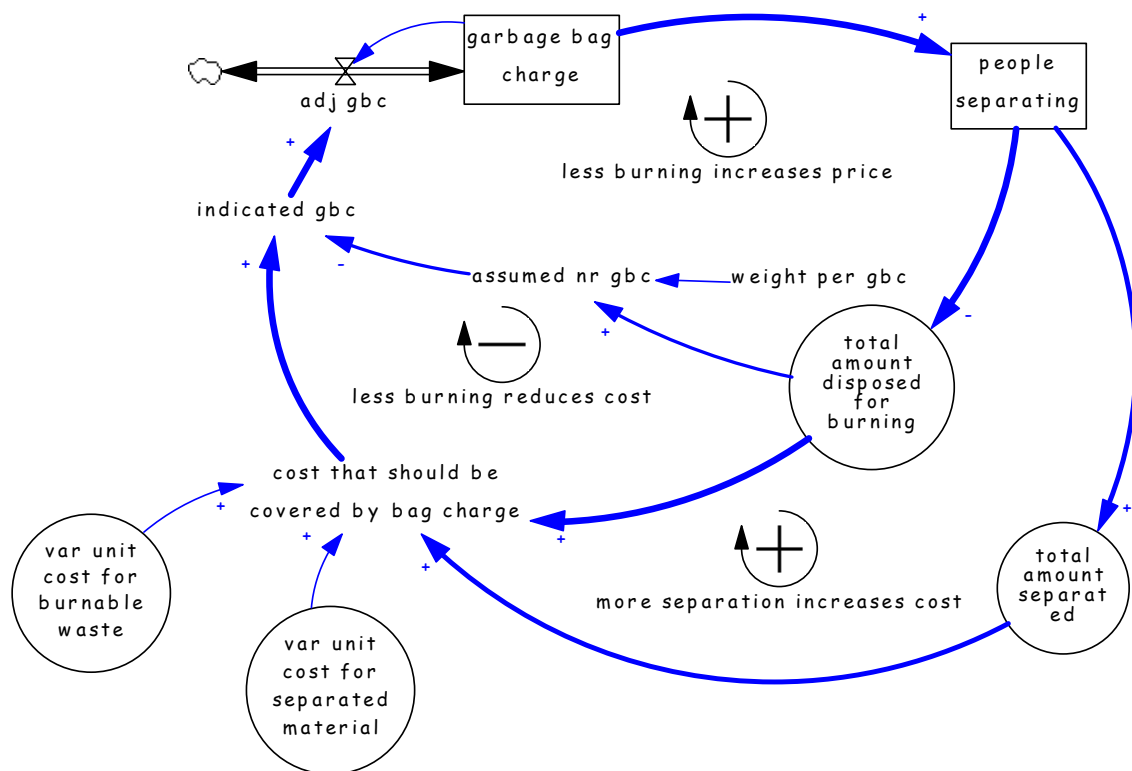
Figure 5.12: Main loops controlling <*garbage bag charge*> adjustment.

The variable cost that should be covered by bag charge is mainly determined by the amount of the different waste qualities and unit costs. Revenues from sources like taxes or from selling separated waste are subtracted.

The following causes tree diagrams (Figure 5.13) illustrate the main variables influencing those costs. They trace the causes determining the variable <*cost swm that should be covered by bag charge*> back to the different waste qualities generated by the different groups of people.

At this point the **local policy sector** is linked to the **household decision sector** respectively the **household waste separation sector** computing the propensity to separate.
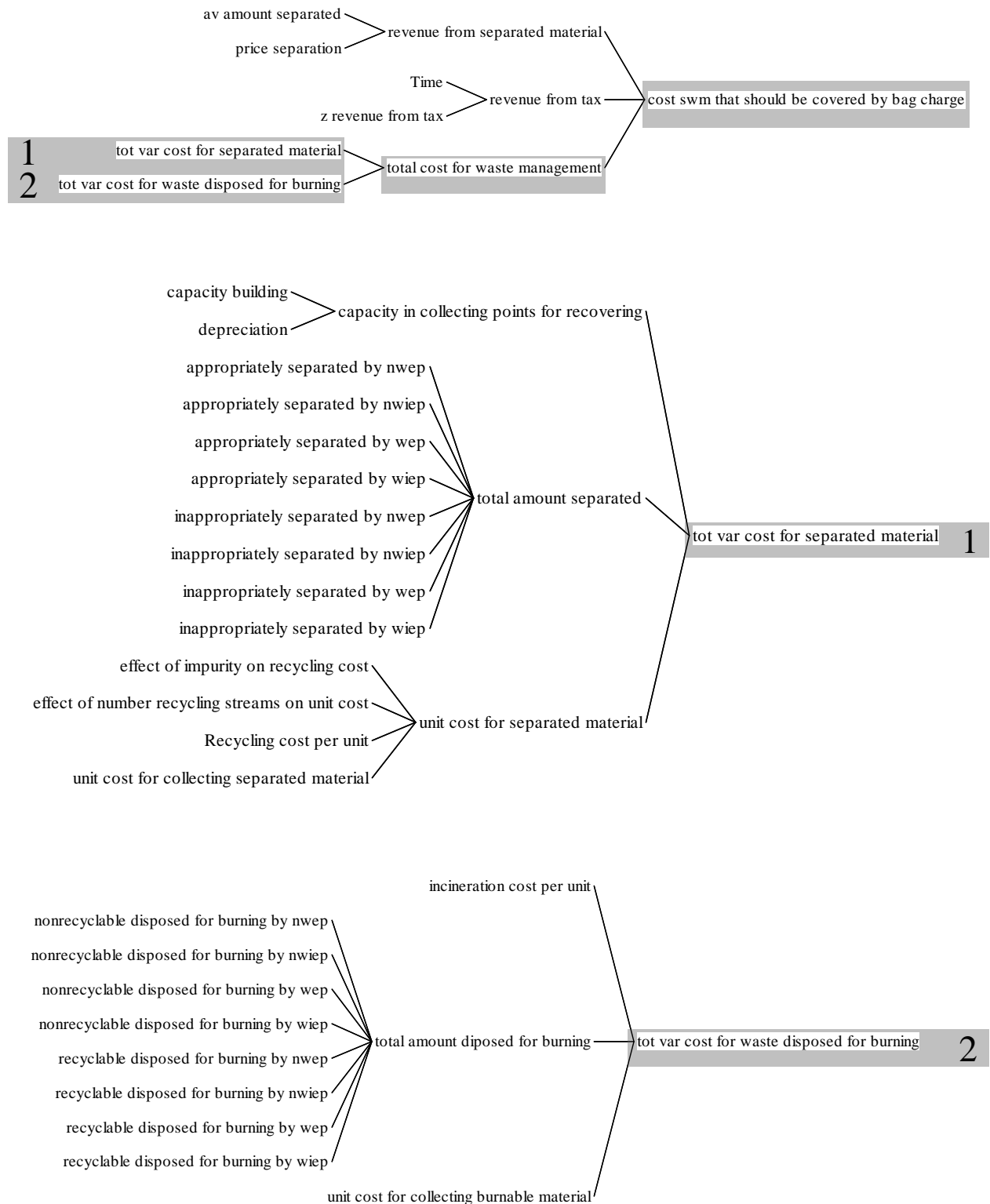
Figure 5.13: Causes trees of *<cost swm that should be covered by bag charge>*

The *<tot variable cost for waste disposed for burning>* and *<tot variable cost for separated material>* are actually determined by both the *<unit cost for collecting burnable material>* (0.1 CHF/kg) and *<unit cost for separated material>* (0.2 CHF/kg) as well as the unit cost given by the incineration *<incineration cost per unit>* and recycling market *<recycling cost per unit>*. The *<recycling cost per unit>* is slightly lower than the *<incineration cost per unit>* (0.1 CHF/kg versa 0.23 CHF/kg). But as can be seen in Figure 5.14 the *<unit cost for separated material>* is influenced by two effects: the *<effect of impurity on recycling unit cost>* and the *<effect of number recycling streams on recycling unit cost>*.
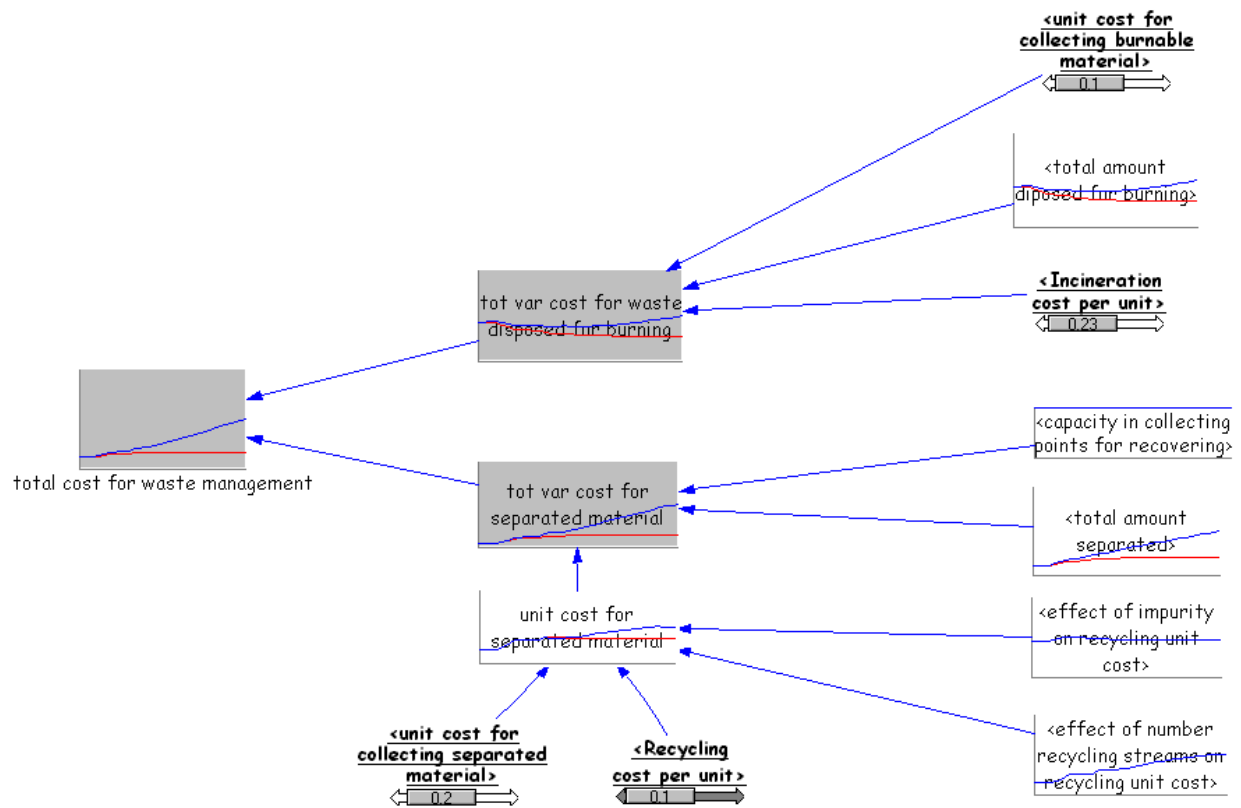
Figure 5.14: Model structure computing *<tot var cost for waste disposed for burning>* and *<tot var cost separated material>* determining the *<total cost for waste management>*.

Policy structure prepaid disposal tax

Figure 5.15 depicts the model structure that allows simulating the impact of a prepaid tax policy. In the policy structure **prepaid disposal tax,** the decision rules guiding the capacity building process in the take back points is illustrated. On the one hand *the <average amount recovered material> determines <capacity building>*. On the other the *<perceived revenue from the prepaid disposal tax>* limits the capacity building process. A gap between the *<average amount recovered material>* and the *<capacity in the collecting points for recovering>* leads to a crowding effect. The crowding effect feeds into the **household decision** and **household separation sector** influencing the rate *<fraction becoming unwilling>*.
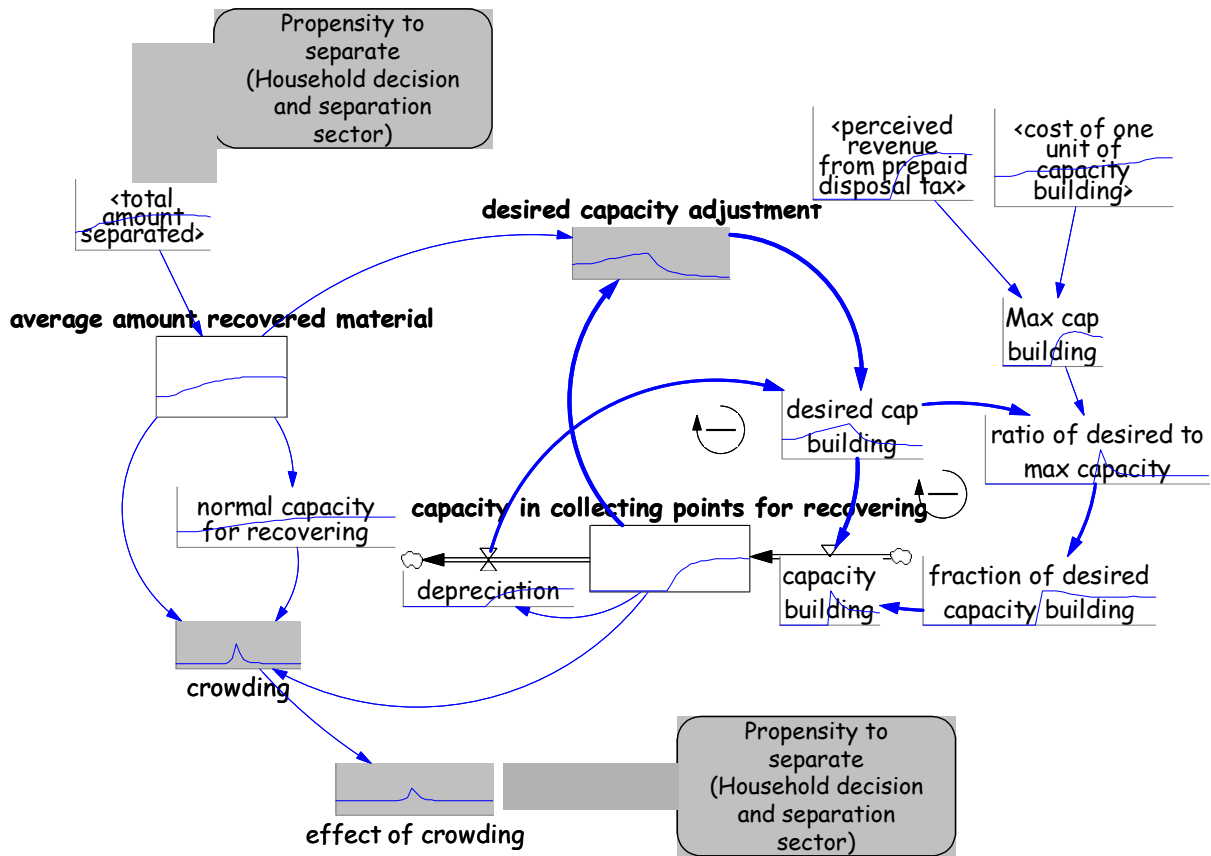
Figure 5.15: Policy structure: Prepaid disposal tax.

5.4.4   Outlook on an extended SD-SWM-model with additional sectors

In the following section an overview of the three main capacity building sectors will be given, including the **local separation sector**, the **recycling sector** and **the production / supply sector** (see Figure 5.16).

The aim of this outline is to enhance the understanding of how the **local separation sector** is embedded in a larger solid waste management system. It gives important background information of some policy and scenario-experiments that are described later on (see Chapter: 5.6).

The local separation sector

In an abstract sense, the average propensity to separate can be seen as the capacity of the citizens to separate the recyclable material. This capacity and the local capacity to collect the separated waste will determine the flow *<separating recyclable material by households>*. Three feedback loops will determine this rate. The backlog *<separated recyclable material in localities waiting to be recycled>* decreases both rates *<net capacity building for separating>* and *<separating recyclable material by households>* and increases the rate *<separated material burning>*. However, an increasing "demand of separated recyclable material" would promote the *<net capacity building process for separating>*. In all of the three different feedback processes, there are both

information and capacity adjustment delays, leading to an unstable system behavior and to inefficiencies.

The recycling sector

The same underlying system-structure affects the rates of flow in the **recycling sector**. As the backlog *<recycled raw material waiting to be turned into goods>* increases, less material will be recycled and less recycling capacity will be built. However, an increase in "demand for recycled raw material" will increase *<net capacity building for recycling>*. As a consequence of an increase in capacity building, the *<<effective nr recycling streams>>* will increase, too.

The production and supply sector

In this sector again, the same system structure will be modeled. The backlog *<recyclable material in goods waiting to be separated>* will be computed by the average amount *<recyclable disposed for burning>* (A2-waste from the **separation behavior sector**). A higher demand of recyclable material in goods by households increases the *<capacity for recycled raw material in production industry>*. The *<actual amount recyclable material>* computed in the **household sector** will measure the "demand of recyclable material in products by households".

This overview of the model structure clarifies the hypothesized reinforcing feedback loop "**trap/chance recycling market**" presented in Figure 5.7. Furthermore, it explains the link of **the local separation sector** to **the recycling sector** and **supply sector** determining the development of recycling markets. Price signals and the perceptions of backlogs will adjust the capacity building process in all three sectors. Different capacity development scenarios will be simulated. It is expected that delays lead to undesired effects such as over-investments in capacity building in the different sectors. Furthermore, this structure should also help understand the trade off between the maximal capacity of citizens to separate and the capacity development in the recycling sector.
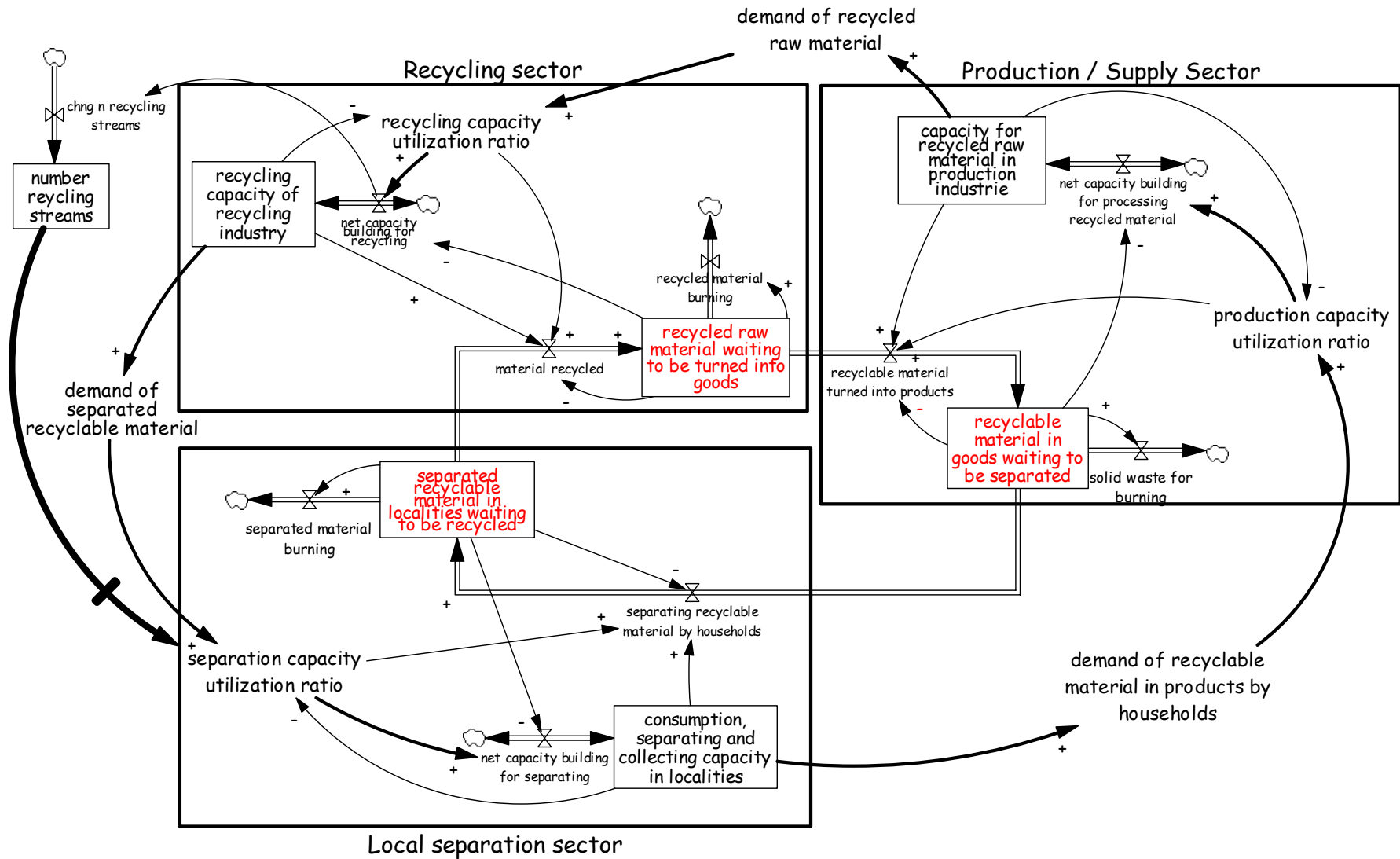
Figure 5.16: Conceptual overview: Effects of demand and backlogs on capacity developments.

5.5   Testing the model

So far, by discussing each sector of the SD-SWM-model the main hypothesized relationships were highlighted and the most important structural elements and dynamics should have become clear. In the following section the test procedures that were applied to test the robustness, consistency and correspondence of the model are described. The main object of testing is to evaluate if the model was appropriate for the purpose. As stated before, the purpose of the actual model is to serve as a learning environment in order to discuss the problem at hand and to inform decision-making. The goal of the model is firstly, to give a plausible explanation about causes of the observed phenomenon in solid waste management, secondly, to provide insights that help cope with the inherent dynamic complexity, and finally to test alternative policies.

It is important to emphasize again that the aim of testing is not to prove that the model is right, since all models are wrong (see, Sterman 2002). Therefore, this chapter aims at revealing the limitations of the current model. Hence, a reflective model testing approach is chosen that exposes the assumptions for critique and improvements. An adequate testing procedure depends on the purpose of the model (Lane 1995).

Having said this, a further aspect "the economics of testing" will be pointed out. Also model testing includes cost and benefit questions, since testing processes are very time consuming. Hence, only those structures, behavior and parameters are tested that are considered to be most influential and critical.

5.5.1   Iterative model testing

As described in Chapter 4.1.3 (Gaining confidence in System Dynamics models), there exist a number of different behavioral and structural tests that are iteratively applied in the process of building the model. Hence, the model already passed a number of tests that helped to build up its consistency and correspondence in the process of model formulation .

Dimensional consistency

Important indicators of consistency are the units of the equations. The current model can be assessed as dimensionally consistent since all parameters in the model have real world meaning and the units in the 250 equations are correct.

However, the dimensional analysis software in Vensim gives a warning that there are ten unit errors discovered (see Figure 5.17). These evolve from graphical functions that are used to plot the variable of interest against time. Since all the ten warnings evolve from a technical feature and not from any inconsistency in real units, there is no reason for worry[57].

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[57] This flaw could be corrected in an improved model version. For this purpose a different technical way of importing an existing dataset has to be used (see Vensim Tutorial: Using Data in Models).
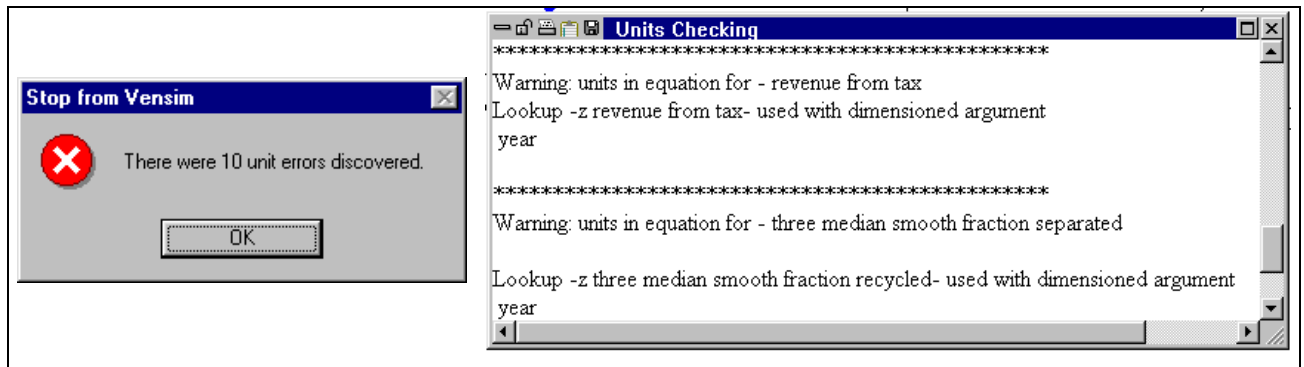
Figure 5.17: Dimensional consistency

Structure assessments tests and behavior reproduction tests

The correspondence and consistency of the model can be evaluated by structure assessment and behavior reproduction tests.

A broad theoretical background and an intensive exchange with experts of the systems helped to build a theory about the functioning of the solid waste management systems. Specifically, it helped to build hypotheses about causal relationships that are captured in the model. Besides knowledge about the real system, the theoretical frameworks were guiding the modeling process as well, resulting in a model structure that is grounded in the relevant knowledge of the system. Each new structural module was evaluated with respect to the plausibility of its behavior (reality check). Does it produce the right behavior for the right reason? Is it consistent? An important help for the model building and testing process are the reference modes *<fraction separated>, <fraction burned>*[58], *<ep willing to separate>,* and the behavior of the different amount of waste as well as the *<garbage bag charge>*. In using the control panel tool of Vensim, the simulated and actual data are plotted together in order to assess the correspondence of the model (see Figure 5.18).

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[58] A three median smooth (running medians, (Mosteller and Tukey 1977)) of the real data of the fraction separated and burned were used in order to smooth out short-term overreactions and high frequency noise.
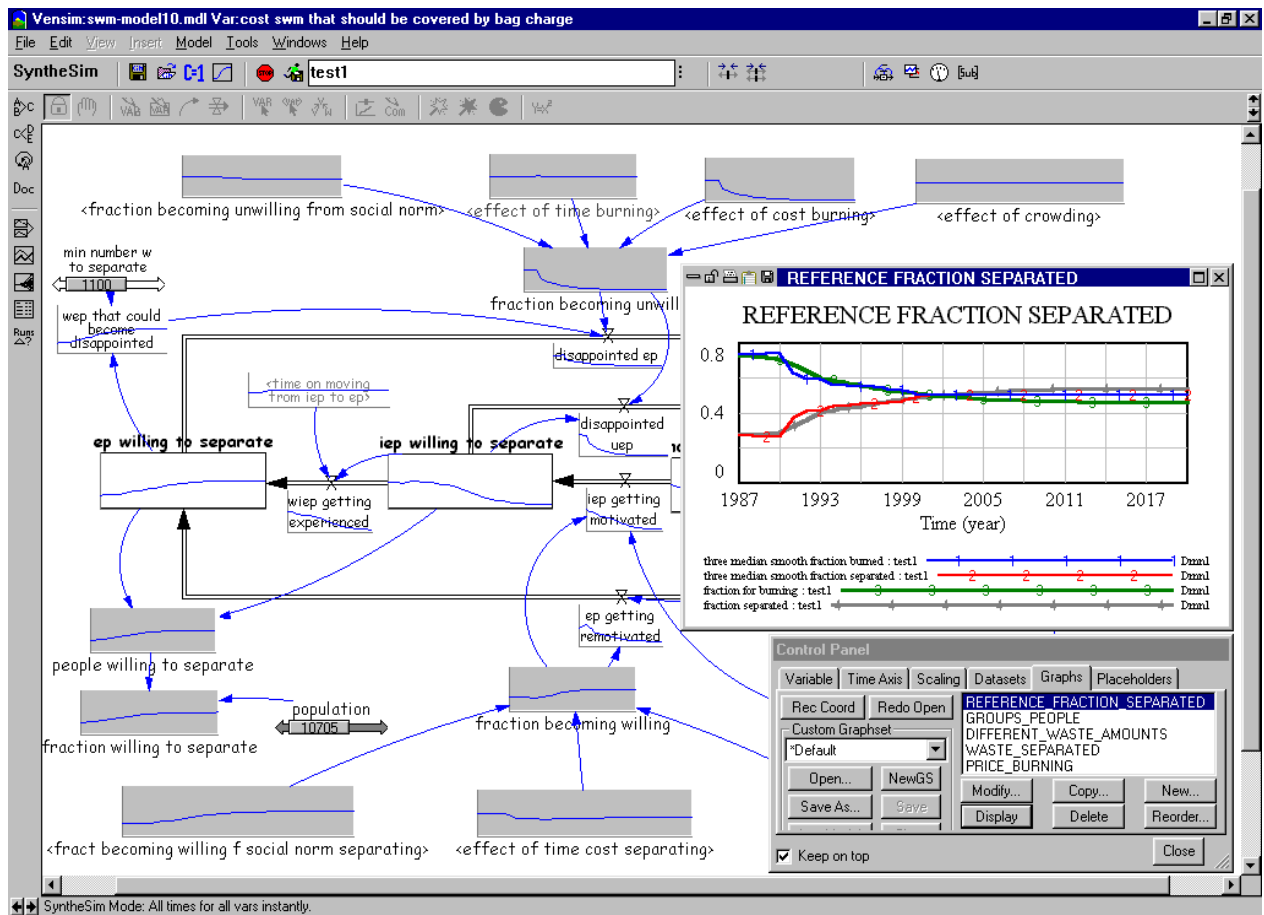
Figure 5.18: Assessing the correspondence of the model to the data.

By applying the behavior reproduction test, many flaws in the structure or graphical functions were discovered and fixed during the process of modeling. The current model shows a good fit (visual assessment) in the *<fraction separated>* and the *<fraction for burning>* (see Chart 5.11). For the time period 1987 to 2001 it exhibits the same pattern of behavior as observed in the data. The good fit and the purpose of the model indicates that there is no need for further statistical behavior reproduction tests, such as Theil's inequality statistics (see Sterman 2000: 875).

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : test —1— 1— 1— 1— 1— 1—	Dmnl
three median smooth fraction separated : test —2— 2— 2— 2— 2— 2—	Dmnl
fraction for burning : test —3— 3— 3— 3— 3— 3— 3— 3—	Dmnl
fraction separated : test —4— 4— 4— 4— 4— 4— 4— 4—	Dmnl

(A)[59]

PRICE AND BUDGET

garbage bag charge : test —1— 1— 1— 1— 1— 1—	Dollars/bag
garbage bag charge exogenous : test —2— 2— 2— 2— 2—	Dollars/bag
price separation : test —3— 3— 3— 3— 3— 3—	Dollars/kg
profit solid waste management : test —4— 4— 4— 4— 4—	Dollars/years
non profit threshold : test —5— 5— 5— 5— 5—	Dollars/years

(B)[60]

Charts 5.11 A-B: Graphical behavior reproduction.

The main stock and flow structure as well as its parameters with the underlying theoretical assumptions have the power to explain the observed behavior with reasonable accuracy.

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[59] Fraction separated in %; therefore the variables are dimensionless (Dmnl)

[60] The units of the Y-axis correspond with the variables and their units indicated in the underline. The underline specify first the variable name (garbage bag charge), second the name of the simulation run (test), third the number of the line (1) and finally the units of the variable (Dollars/bag).

However, an additional graphical behavior reproduction test has to be discussed. Chart 5.11 (B) reveals an obvious discrepancy between the simulated mode of behavior (line 1 – *<endogenously computed garbage bag charge>*) and the observed in the data (line 2 – *<given data garbage bag charge>*).

The *<endogenously computed garbage bag charge>*) shows a continuous growth till it seeks equilibrium. However, the real data reflect a discreet step behavior in the price adjustment process. This discrepancy indicates a missing structure in the model.

In the real world the price adjustment process is determined by institutional and political structures. These keep the price on the same level till the pressure in the system passes a threshold (when the deficit in solid waste management gets to high) resulting in a price adjustment act.

However, these structures do not matter for the model purpose. Furthermore, the simulated price graph passes the given data indicating that the structure in the model computes the price accurate enough and produces overall the same mode of behavior in the *<fraction separated>*. In addition the observed price dynamics give some insights about the system behavior respectively the dynamics of the garbage bag charge and the phenomenon of the recurring deficit. Those will be addressed in the Chapters 5.6 (Model behavior and policy-experiments), as well as in 6.1 (Policy implications).

5.5.2   Extreme condition tests

A further test series - extreme condition tests - were conducted. They help analyze the robustness of the model under extreme variations of important parameters and policies. In addition they indicate wrong and missing model structure that should control the model and system behavior under extreme situations. In those situations other feedback loops will become dominant than under normal conditions, when the model operates with the observed and realistic model parameters.

In the following paragraph the three extreme conditions test "zero recycling streams" and "no waste generation" as well as a case with "hundred percent of recyclable waste" will be described and discussed. The "extreme condition tests" interface facilitates the replication of these experiments (see Appendix A1 Overview model structure).

Zero recycling streams

The extreme condition "zero recycling streams" tests if the model would behave plausibly when no recycling opportunities were given. In reality, under this situation no one could separate; therefore, the amount separated would be zero. For simulating this condition, the parameters "initial number recycling streams" is set to zero.

Chart 5.12 (A) portrays a zero *<fraction separated>* (line 4). This result was expected. All the garbage set aside for burning, the *<fraction for burning>* is therefore one (line 3).

Chart 5.12 (B) shows the dynamics in groups of people. In 1987, nearly half of the population were willing to separate. Since there are no recycling opportunities the *<ep willing to separate>* get disappointed (graph 1, declines) and nearly the whole population becomes unwilling to separate (growth in graph 3 *<iep not willing to separate>*) towards the end of the simulation horizon. This simulated behavior seems to be plausible. Although there are some dynamics in the systems there is no dynamic in the different waste qualities (e.g. the *<amount of separated>* stays constant).

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : test1	Dmnl
three median smooth fraction separated : test1	Dmnl
fraction for burning : test1	Dmnl
fraction separated : test1	Dmnl

(A)

MOVING PEOPLE

ep willing to separate : test1	people
iep willing to separate : test1	people
iep not willing to separate : test1	people
ep not willing to separate : test1	people
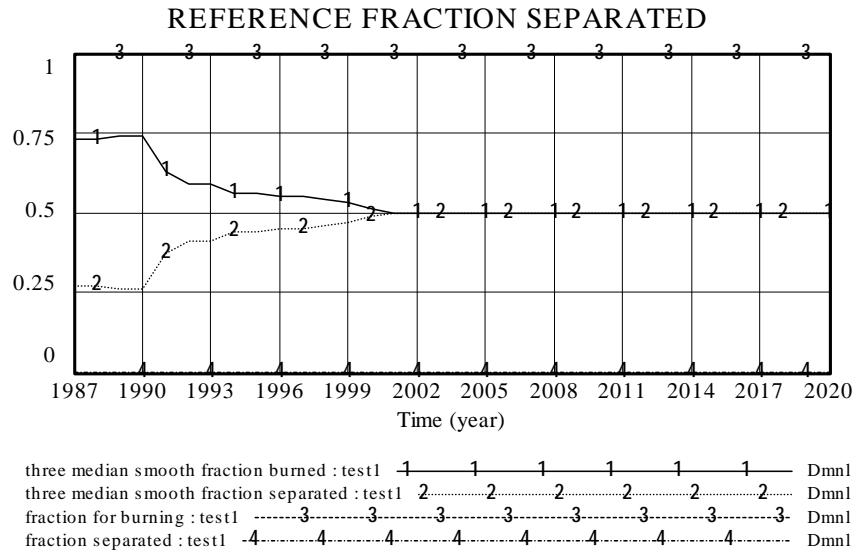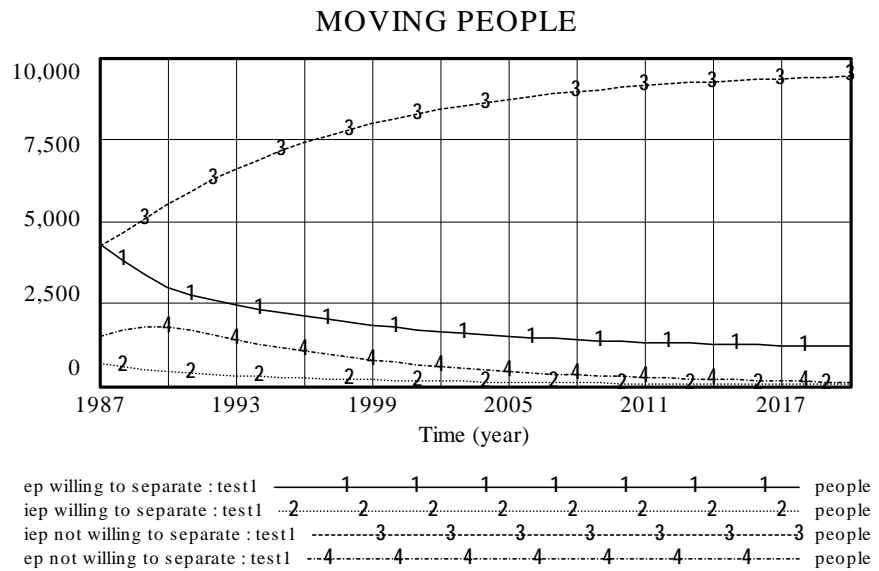
(B)

Charts 5.12 A-B: Dynamics under extreme condition "zero recycling stream"

Zero waste generation per capita

The second extreme condition test "zero waste generation per capita" simulates an unrealistic situation in which no waste will be produced. Waste needs neither to be burned nor recycled. The parameter *<solid waste generation normal>* is set to zero.

The simulation runs in Chart 5.13 portrays that both the <*fraction separated*> and <*fraction for burning*> (graph 3 and 4) will be zero. This result seems plausible since there is no garbage generation in the model.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : test1 ⎯1⎯⎯1⎯⎯1⎯⎯1⎯⎯1⎯⎯1⎯⎯ Dmnl
three median smooth fraction separated : test1 2⋯⋯⋯2⋯⋯⋯2⋯⋯⋯2⋯⋯⋯2⋯⋯⋯2⋯⋯ Dmnl
fraction for burning : test1 ⎯⎯⎯3⎯⎯⎯3⎯⎯⎯3⎯⎯⎯3⎯⎯⎯3⎯⎯⎯3⎯⎯⎯3⎯ Dmnl
fraction separated : test1 -4⎯⎯⎯4⎯⎯⎯4⎯⎯⎯4⎯⎯⎯4⎯⎯⎯4⎯⎯⎯4⎯⎯ Dmnl
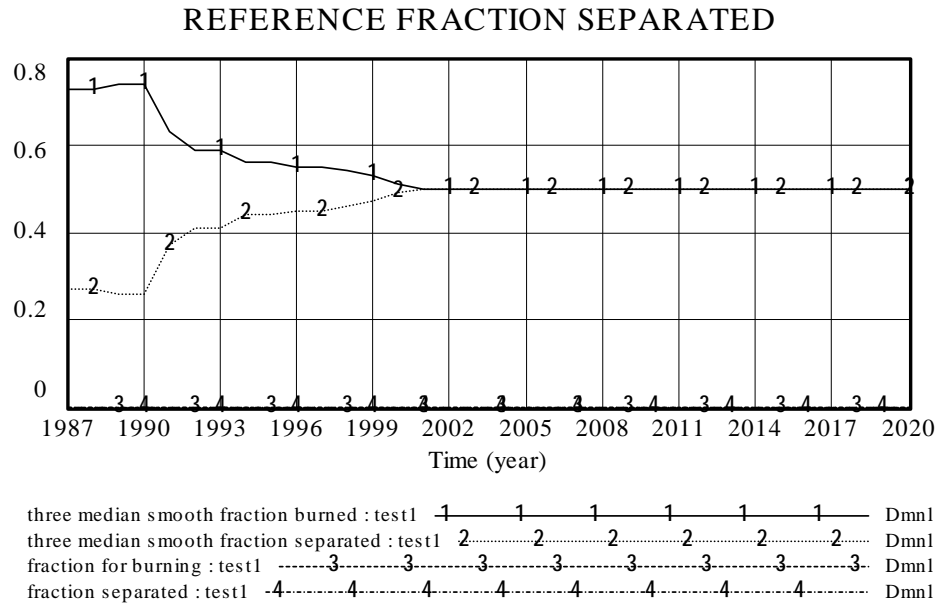
Chart 5.13: Dynamics under extreme condition "zero waste generation per capita".

At this point it would be interesting to test the dynamics in the system with hundred percent recyclable waste.

Hundred percent recyclable waste

A "hundred percent recyclable waste"-scenario reflects an economy that only produces recyclable products. In order to test this extreme condition, the graphical function <*z multiplier for recyclable material from number of recycling stream*> is set to 2.27 for all x values. Multiplying the <*normal fraction recyclable*> (set to 44%) with this value yields 100% recyclable waste in the model[61]. Charts 5.14 A-D illustrate the behavior of the model under the assumption that 100% of the waste is recyclable. In Chart 5.14 A, graph 4 indicates that under this condition the <*fraction separated*> grows till it seeks equilibrium around 80%. This growth is caused by the increasing number of <ep willing to separate> (graph 1, B).

However, Chart 5.14 C illustrates that impurity peaks twice due to the price effects (graph 5 <*total amount inappropriately separated*>) but will attenuate towards an equilibrium level of 55 000 kg/year. This is only a small fraction 1.28%. (<*total amount inappropriately separated*> of 55 000 kg/year divided by the <*total amount separated*> of 2.862 M kg/year).

Under this condition the model shows a gap of 20% between total amount recyclable (graph 4) and the <*total amount separated*> (graph 3). This gap is noteworthy and will be addressed further in Chapter 5.6 (Model behavior and policy-experiments). Furthermore, the model computes an increasing garbage bag charge that levels off by 5.3 CHF/bag (D).

Given the reference policy those simulated patterns also seem plausible.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : test1	Dmnl
three median smooth fraction separated : test1	Dmnl
fraction for burning : test1	Dmnl
fraction separated : test1	Dmnl

(A)

MOVING PEOPLE

ep willing to separate : test1	people
iep willing to separate : test1	people
iep not willing to separate : test1	people
ep not willing to separate : test1	people

(B)

Different waste amounts

total amount solid waste : test1	kg/year
total amount diposed for burning : test1	kg/year
total amount separated : test1	kg/year
total amount recyclable material : test1	kg/year
total amount inappropriately separated : test1	kg/year

(C)

PRICE_BURNING

garbage bag charge : test1	1——1——1——1——1——1——1——1——1	Dollars/bag
garbage bag charge exogenous : test1	2········2········2········2········2········2········	Dollars/bag
price separation : test1	----3------3------3------3------3------3------3------3-----	Dollars/kg

(D)

Charts 5.14 A-D: Dynamics under extreme condition "hundred percent recyclable waste"

Overall, the three extreme condition tests illustrate that the model behaves in a plausible manner even under extreme conditions. This gives evidence that the model is robust. The following description of the model behavior under different policy-experiments and the sensitivity analysis give further evidence of its relevance and usefulness.

5.6   Model behavior and policy-experiments

Considering the purpose of the model sufficient confidence has been established in the model structure. Following the test-logic outlined in Chapter 4.1.3, the overall model behavior under different policies was analyzed. Hence, in this section, different policy-experiments such as simulating the actual implemented solid waste policy are reported. These experiments allowed for test of correspondence of model behavior to the reference modes and analysis of dynamics of different policies. Besides different policy-experiments, sensitivity analysis will be conducted and the results will be discussed. Based on these findings policy-implications can be derived that are discussed in Chapter 6 (Discussion and reflection on policy, theory and method).

The main stock and flow structure of the model (see Figure 5.10: Changes in citizen's willingness to separate) has similar characteristics as basic epidemic and innovation diffusion models such as the SIR-model[62] or the Bass-model[63] (see Kermack and McKendrick 1927,

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[62] The SIR-model is widely used in epidemiology for simulating the infection process of acute diseases. It mainly contains three stocks, the susceptible population (S), the infectious population (I) and the recovered population (R).

[63] The Bass-diffusion-model mimics the diffusion of innovation of new product growth and is widely used in marketing and for strategy-development and management of technology.

Bass 1969; Bass, Krishnan et al. 1994 in Sterman 2000: 300ff). The diffusion process is boosted by the second-order reinforcing feedback structures. The exponential growth or decline is limited by first order control loop structures, controlling the overall growth capacity (such as the number of *<people not willing to separate>* and *<people willing to separate>)* hence, resulting in s-shaped growth.

An important characteristic of the second order-models is the tipping point. If the diffusion process does not take off, a new idea, a new product, a disease or even a policy initiative is likely to die. The question of whether in our case the policy initiative will succeed is a question about which feedback loops are dominant, when the new policy is implemented in a community. The recycling initiative will succeed if the positive loops controlling the rates **"getting motivated"** dominates the positive loops controlling the rates **"getting disappointed"**[64] otherwise the initiative will fail (see Figure 5.19).

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[64] Probably, this loop could also be named "getting discouraged" or "demotivated", since different psychological concepts could be used to explain the process that lead people to decide against waste separation. However, in this book this loop will be called uniformly "getting disappointed".
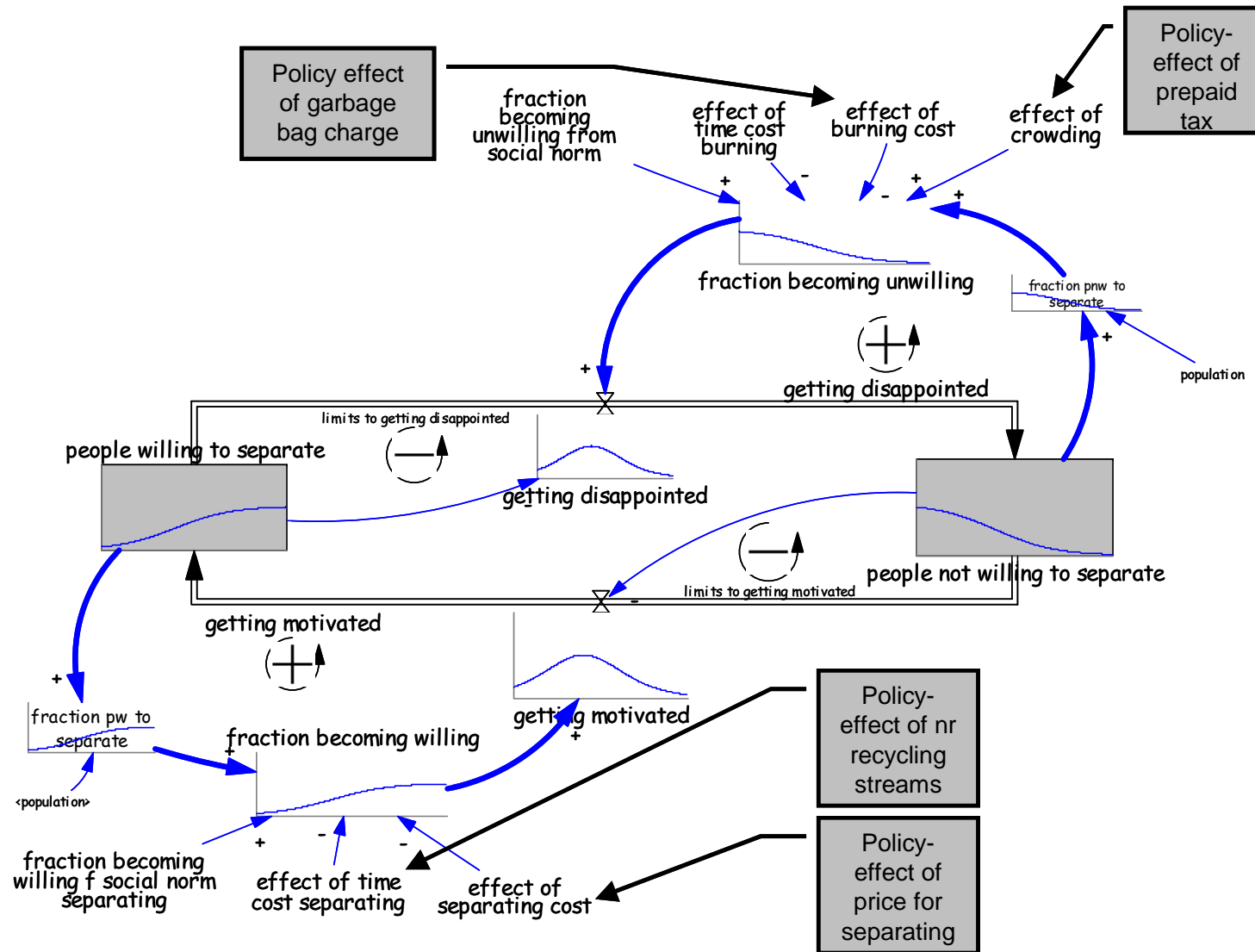
Figure 5.19: Simplified model structure and policy effects.

Different policy-interventions have different effects on the two positive feedback loops. A higher garbage bag charge weakens the loop **"getting disappointed"** whereas an increase in the *<effective nr recycling streams>* increases the *<effect of time cost separating>*. This will weaken the loop **"getting motivated"**. A price for separated material will have the same effect. Furthermore, it is assumed that a prepaid tax could lead to a *<effect of crowding>* strengthening the loop **"getting disappointed".** The strength of those loops will mainly determine the model behavior. However, in the full-blown model version numerous further loops will control these diffusion-loops and subsequently the model behavior.

In the following paragraph the model behavior will be explained around different policy-experiments. Mainly three streams of policy-experiments will be conducted:

1. back-casting policy-experiments depicting the actual policy in place (inertia policy) and the implementation of alternative policy combinations going back to 1987

2. forecasting[65] policy-experiments analyzing the effect of new policies such as implementing prepaid taxes or prices for separated material for the time horizon from 2004-2020

3. policy-experiments under different scenarios over the time horizon 1987 to 2020.

All the different experiment-designs allow conducting comparative policy analysis under controlled conditions. Hence, the behavior pattern resulting from different policies can be compared and explained under similar conditions. In addition to these experiments assuming perfect information about the system parameters, the policy sensitivity of some crucial parameters will be analyzed in order to test the robustness of these policy implications under uncertainty and imperfect information.

The SD-SWM-model created in Vensim has different flight-simulators in order to facilitate the replication of the different policy-experiments (see Appendix A1).

5.6.1 Back-casting policy-experiments

The objective of the back-casting policy-experiments is twofold: Firstly, the model structure will be tested: Is it able to produce the behavior observed in the real world? Secondly, the simulated dynamics help explain the observed behavior. Especially some basic insights about effects of single policy and different policy-packages shall be gained.

The Table 5.7 explains the design of back-casting policy-experiments. Each experiment is specified by a combination of different policy-levers that determines a policy-package. In the model the different policy-levers can be switched on (1) or off (0) in order to specify a policy-package. Different combinations of the two main policies (implementing "garbage bag charge" and "increasing the number of recycling streams") determining policy-packages will be tested. In **inertia policy 1** the garbage bag charge is exogenously given and in **inertia**

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[65] The term forecasting refers to the time horizon in the future and indicates that the effect of a policy interventions made in the future will be analyzed. Contrarily, the term back-casting refers to a policy intervention that was made in the past.

policy 2 it is endogenously computed by the model, otherwise the two policy bundles are the same.

Names of policy-experiments	Policy-lever		
	Garbage bag charge exogenous	Garbage bag charge endogenous	Increase in number streams
Back-casting			
Inertia policy1 (Base run1)	1	0	1
Inertia policy 2 (Base run2)	0	1	1
Garbage bag charge policy		1	0
Increase nr recycling streams		0	1
Ignorance policy		0	0

Table 5.7: Design of the back-casting policy-experiments.

The simulation runs show the dynamics of the model-structure under specific policy-packages. The outcome for each policy-experiment will be measured with the following indicators / variables of interest:

- The simulated values of *<fraction separated>*, *<fraction for burning>* are depicted against the smoothed real data.

- number of the different groups of people willing respectively not willing to separate: *<ep willing to separate>*, *<iep willing to separate>*, *<iep not willing to separate>*, *<ep not willing to separate>*

- *<total amount appropriately separated>* and *<total amount inappropriately separated>*. These amounts will be depicted against the *<total amount recyclable material>*.

- *<garbage bag charge>* and *<price for separating>* and the *<profit of solid waste management>*.

Those indicators are thought to be crucial for measuring the performance of the policy-packages.

Inertia policy

The base run describes the model behavior with the actual policies in place (**inertia policy 2**): an increase in *<effective nr recycling streams>* and an increasing *<garbage bag charge>* (endogenously computed). The simulated *<fraction separated>* and *<fraction for burning>* closely tracks the smoothed real data (see Chart 5.15 A). There is a clear trend of growth in the *<fraction separated>*. Based on the historical growth trend the model data indicate a further increase in the *<fraction separated>* till it seeks equilibrium that will be slightly higher (54%) than the actual fraction (50%).

The dynamics are created by the flow of people respectively by changes in the number of the four different groups of people willing / not willing to separate. Chart 5.15 B shows a clear increase in the number of *<ep willing to separate>* beginning in 1991, and a decrease in the number of *<iep not willing to separate>*.

Chart 5.15C illustrates an increasing trend in separated material. However, the price incentives lead to a sudden increase in the *<tot amount inappropriately separated>* in 1991. But the decreasing trend in the number of *<iep not willing to separate>* causes a smoothed decline in the *<tot amount inappropriately separated>* seeking equilibrium. This dynamics represents a classical "first-worse-before-better" behavior pattern. As a consequence of this behavior, the gap between *<total amount recyclable material>* and the *<tot amount appropriately separated>* decreases, resulting in a smaller constant gap.

Chart 5.15 D illustrates the increase in the *<garbage bag charge>*. The model structure computes a *<garbage bag charge>* that seeks a zero profit goal. A change in the *<effective nr recycling streams>* creates the opportunity for people to separate more material, which has two effects. Firstly, it reduces the *<total amount disposed for burning>* resulting in less revenue. Secondly, it increases the cost for collecting the separated material. These two effects result in a short and minimal budget deficit due to price adaptations delays in the *<garbage bag charge>*. The *<garbage bag charge>* levels off at 2.1 CHF/bag (D).

However, those price adaptation delays are much longer in the real system. This adaptation delay creates the observed budget deficit in the real world. Chart 5.15 E illustrates this case in the **inertia policy 1-**experiment. It is simulated with the *<garbage bag charge exogenous>* resulting in a budget deficit between 1993 and 2000, appearing again after 2001 (see gap between line 4 and 5 *<profit solid waste management>* and *<non-profit threshold>*).
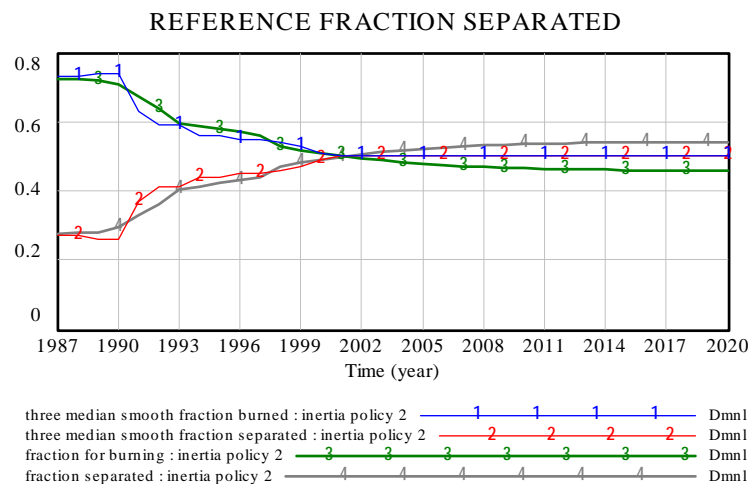
(A) (Line 1 and 2 are three median smoothed real data)

MOVING PEOPLE

ep willing to separate : inertia policy 2 — 1 — 1 — 1 — 1 — 1 — people
iep willing to separate : inertia policy 2 — 2 — 2 — 2 — 2 — 2 — people
iep not willing to separate : inertia policy 2 — 3 — 3 — 3 — 3 — 3 — people
ep not willing to separate : inertia policy 2 — 4 — 4 — 4 — 4 — 4 — people

(B)

WASTE SEPARATED

total amount appropriately separated : inertia policy 2 — 1 — 1 — 1 — 1 — kg/year
total amount recyclable material : inertia policy 2 — 2 — 2 — 2 — 2 — kg/year
tot amount inappropriately separated : inertia policy 2 — 3 — 3 — 3 — 3 — kg/year

(C)

PRICE AND BUDGET

garbage bag charge : inertia policy 2 — 1 — 1 — 1 — 1 — Dollars/bag
garbage bag charge exogenous : inertia policy 2 — 2 — 2 — 2 — 2 — Dollars/bag
price separation : inertia policy 2 — 3 — 3 — 3 — 3 — 3 — Dollars/kg
profit solid waste management : inertia policy 2 — 4 — 4 — 4 — 4 — Dollars/years
non profit threshold : inertia policy 2 — 5 — 5 — 5 — 5 — Dollars/years

(D)

PRICE AND BUDGET

(E)

Charts 5.15 A-E Dynamics back-casting policy-experiment "inertia policy"

Alternative back-casting policy-experiments

Since the base run explains the historical behavior pattern with the actual policy in place, the model can be used as a laboratory to address the "what-if"-question: What would have happened if other policies had been chosen? The objective of these policy-experiments is twofold: Firstly, they help gain further confidence in the model and to test its relevance. Secondly, they may help explain the outcome of different recycling initiative in other localities matching the virtual policy-experiments[66]. Again, a simple "flight-simulator" assists the replication of the back-casting experiments (see Appendix A1).

Garbage bag charge policy

In the **garbage bag charge policy** only price incentives to separate were given. Since 1991 people have to pay a price per garbage bag. In 2000 the price increased by nearly 100%. The *<total amount recyclable material>* in the waste remained constant. According to Charts 13 A-C, the policy increases the *<fraction separated>* slightly till it seeks equilibrium around 38% (Chart 5.16 A). Over time, nearly all the people become willing to separate (Chart 5.16 B). In Chart 5.16 C, the *<total amount appropriately separated>* finds equilibrium at a higher level. Due to the price incentives, the *<tot amount inappropriately separated>* peaks around 1991 and decreases gradually to a lower stable level. Furthermore, the gap between the *<total amount recyclable material>* and the *<total amount appropriately separated>* decreases concluding in a constant gap. In Chart 5.16 D, the *<garbage bag charge>* increases till it seeks equilibrium at 0.86 CHF/bag

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[66] With this feature the model would fall into a typology called a generic structure: "A generic structure is a model that captures the fundamental causal relationships that appear in a variety of pattern models within a particular category" (Radzicki 2003:151). If the model can be applied to different localities and if it is able to mimic the observed dynamic in solid waste management then there is high confident that it captures fundamental causal relationship explaining the separation behavior of citizens or the propensity to separate in a generic way.

and the budget deficit *<profit solid waste management>* smoothly goes to zero (D, line 1 and gap between line 4 and 5). The equilibrium *<garbage bag charge>* (line 1) is lower than in the inertia policy (line 2) *<garbage bag charge exogenous>* due to a smaller *<total amount recyclable material>* causing less uncovered costs.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : bag charge policy	Dmnl
three median smooth fraction separated : bag charge policy	Dmnl
fraction for burning : bag charge policy	Dmnl
fraction separated : bag charge policy	Dmnl

(A)

MOVING PEOPLE

ep willing to separate : bag charge policy	people
iep willing to separate : bag charge policy	people
iep not willing to separate : bag charge policy	people
ep not willing to separate : bag charge policy	people

(B)

WASTE SEPARATED

total amount appropriately separated : bag charge policy ——1——1——1—— kg/year
total amount recyclable material : bag charge policy ——2——2——2——2—— kg/year
tot amount inappropriately separated : bag charge policy ——3——3——3——3—— kg/year

(C)

PRICE AND BUDGET

garbage bag charge : bag charge policy ——1——1——1——1—— Dollars/bag
garbage bag charge exogenous : bag charge policy ——2——2——2—— Dollars/bag
price separation : bag charge policy ——3——3——3——3—— Dollars/kg
profit solid waste management : bag charge policy ——4——4——4——4 Dollars/years
non profit threshold : bag charge policy ——5——5——5——5—— Dollars/years

(D)

Charts 5.16 A-D: Dynamics back-casting policy-experiment "bag charge policy"

Increase in number recycling streams

Following, the alternative back-casting policy-experiment **increase nr recycling streams** will be described. A growing *<effective nr recycling streams>* both creates more recycling opportunities and also increases the total amount of recyclable material. Charts 5.17 A-D illustrate a slight increase in the *<fraction separated>* between 1987 and 1993. However, after 1993 the fraction starts to decrease due to a sharp increase in people becoming unwilling to separate, (see line 3 *<iep not willing to separate>)*. The *<total amount appropriately separated>* falls below its initial value and the *<tot amount inappropriately recycled>* will increase as the number of *<iep not willing to separate>* increases. The compliance gap increases. Here, the model parameters operate near the tipping point. A higher maximal acceptable time for recycling could lead to an opposite policy outcome. This policy sensitivity will be analyzed in Chapter

5.6.4 (Sensitivity analysis). Chart D shows an immense budget deficit due to the missing income from the garbage bag charge (compare line 4 *<profit solid waste management>* and line 5 *<non-profit threshold>*).

REFERENCE FRACTION SEPARATED

(A)

MOVING PEOPLE

(B)

WASTE SEPARATED

(C)

PRICE AND BUDGET

(D)

Charts 5.17 A-D: Dynamics back-casting policy-experiments "increase nr recycling"

Ignorance policy

In the **ignorance policy** strategy, there are no price incentives (no garbage bag charge is levied) and no changes in the *<effective nr recycling streams>* will take place. Therefore, the *<total amount recyclable material>* in the waste does not change over time.

Charts 5.18 A-D portray the dynamics of the **ignorance policy**: the *<fraction separated>* stays at a constant level. Over time, there is only a slight increase in the number of people become to separate. In this experiment the number *<ep willing to separate>* seeks equilibrium at around 5234 people on a lower level than in the **inertia policy** indicating that the loops **"getting motivated"** and **"getting disappointed"** are balanced. The *<total amount appropriately separated waste>* stays nearly the same. Furthermore, there is a remarkable gap between *<total amount appropriately separated>* and *<total amount recyclable material>* indicating a low policy compliance (Chart 5.18 C). The budget deficit stays constants over time (see D: line 5 and line 4).

REFERENCE FRACTION SEPARATED

(A)

MOVING PEOPLE

ep willing to separate : ingnorance policy ——1——1——1——1——1——1—— people
iep willing to separate : ingnorance policy ——2——2——2——2——2——2—— people
iep not willing to separate : ingnorance policy —3——3——3——3——3——3— people
ep not willing to separate : ingnorance policy —4——4——4——4——4— people

(B)

WASTE SEPARATED

total amount appropriately separated : ingnorance policy ——1——1——1—— kg/year
total amount recyclable material : ingnorance policy ——2——2——2——2—— kg/year
tot amount inappropriately separated : ingnorance policy —3——3——3——3— kg/year

(C)

PRICE AND BUDGET

garbage bag charge : ingnorance policy ——1——1——1——1—— Dollars/bag
garbage bag charge exogenous : ingnorance policy ——2——2—— Dollars/bag
price separation : ingnorance policy ——3——3——3—— Dollars/kg
profit solid waste management : ingnorance policy ——4——4—— Dollars/years
non profit threshold : ingnorance policy ——5——5——5—— Dollars/years

(D)

Charts 5.18 A-D: Dynamics back-casting policy-experiments "ignorance policy".

Table 5.8 compares the value of *<garbage bag charge>* from the different back-casting policy-experiments at different time points. Under the inertia policy 2 the *<garbage bag charge>* increases further due to the slight increase in the *<fraction separated>* after 2000. This indicates that as long as the *<fraction separated>* has not yet reached equilibrium, further prices adjustments have to take place in order to meet the zero deficit goal.

Garbage bag charge, CHF/bag (Price burning CHF/kg)	1987	1991	2000	2004	2020
Back-casting policy-experiment					
Inertia policy 1	0	0.9	1.8	1.8	1.8
Inertia policy 2	0	0.76	1,87	1,98	2.07
Garbage bag charge policy	0	0.68	0.87	0.87	0.87
Increase nr recycling streams	0	0	0	0	0
Ignorance policy	0	0	0	0	0

Table 5.8: Garbage bag charge under the back-casting experiments

5.6.2   Insights from the back-casting experiments

The overview of the back-casting policy-experiments (see Table 5.9) shows that the combinations of garbage bag charge policy and offering more recycling streams in the **inertia policy** gives the best outcome concerning the *<fraction separated>*. However, this policy also results in two unintended consequences. On the one hand the (garbage bag charge) leads to a deficit in the solid waste management budget. This deficit is a result of the internal dynamics in the amounts of the different waste qualities. These findings substantiate the **dynamic hypothesis** explained in Figure 5.5. Furthermore, once a price incentive creates a clear gain for citizens to separate, a further increase in the price does not show any remarkable effect on the *<fraction separated>*. On the other a discreet increase worsens the quality of the separated material in the short term before it becomes better. Citizens not willing to separate might try to avoid the disposal cost by putting un-recyclable material in the recycling streams. However, this effect will be attenuated since more people will become willing to separate.

A further insight from simulating alternative policy options is related to the question: Which cues do we use to observe the policy performance? A glimpse of the *<fraction separated>* simulated in three alternative policies experiments could tell us that there is only a small difference (the *<fraction separated>* stays relatively low in all three alternative policy-experiments, between 25-33%). But the simulation runs of the experiments highlight that there are important differences in the impact and outcome of each policy. Only the

experiment **garbage bag charge policy** will show a robust policy impact motivating people to participate in recycling programs and improving the outcome.

Conversely, the two experiments **ignorance policy,** and **increase nr recycling stream** can either motivate or overwhelm the citizens, resulting either in a slightly better outcome or in a worse outcome (with less *<total material appropriately separated>),* (see Table 5.9).
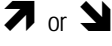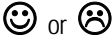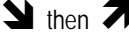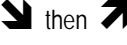
Policy-packages Results	Inertia policy Bag charge and more streams	Garbage bag charge policy	Increase number recycling streams	Ignorance policy
Variable of interest	Fraction separated ⬀⬀	Fraction separated ⬀	Fraction separated ⬀ or ⬊	Fraction separated ➔
Impact on Citizens	Citizens get motivated ☺	Citizens get motivated ☺	Citizens could become overwhelmed ☺ or ☹	Citizens get disappointed 😐
Outcome in Quality	Quality ⬊ then ⬀ (deficit and resistance)	Quality ⬊ then ⬀ (resistance)	Quality (Not a real issue)	Quality ➔

Table 5.9: Overview of back-casting policy results

In sum, the experiments give evidence of the superiority of a mixed strategy, motivating citizens to participate and offering adequate opportunities. When motivating citizens is the only strategy used, contextual factors could constrain their intention to separate. Similarly, if the focus is only on improving contextual factors, personal factors (such as a low willingness to spend time on separating) could inhibit the success of the policy initiative. However, the side effects of extrinsic motivation (giving price incentives that results in higher impurity) can be harmful for the overall recycling initiative. High impurity can become a trap for the recycling market. Therefore, the challenge for local authorities would be to find policy strategies that would increase intrinsic motivation to separate.

Another observation is that in all policies there remains a gap between the *<total amount recyclable material>* and the *<total amount appropriately separated>*. The width of the gap can be interpreted as the compliance-gap to separate. It depends not only on the number of people willing to separate and on the purity but also on other factors such as learning processes, changes in habits, and the design of the products but also on the indolence of people. The simulation runs illustrate that a 100% separation-compliance will never be reached.

The insights about a **maximal separation-compliance** and a **maximal separation capacity** gives evidence that structural elements will constrain the overall possible propensity to separate at the local level. We can conclude that in the given context the inertia

recycling initiative is successful and the potential for further improvement is small under the given conditions.

5.6.3 Forecasting policy-experiments

The previous policy-experiments give evidence that the model structure is able to explain some observed real world dynamics of solid waste management. Having established enough confidence in the model structure, we can use the model as a virtual world to conduct controlled experiments. The simulation runs explaining the dynamics of alternative policy-experiments are hypothetical outcomes based on the causal theory and are seen as dynamic hypothesis. They postulate behavior patterns and do not predict point values. The model is a laboratory in which we know the exact experiment design and condition. Under this controlled condition we are interested in the dynamic outcome associated with pattern of behavior pattern changes.

Two main policy regimes will be tested. A policy regime with prepaid disposal taxes and a policy stream with pricing the separated material. Each policy-package specifies the design of the policy-experiment, respectively and stresses changes in the conditions. The dynamics of the different conditions are analyzed in order to understand the interactions of different policy-combinations. Figure 19 illustrates those interventions influencing the main loops determining system behavior.
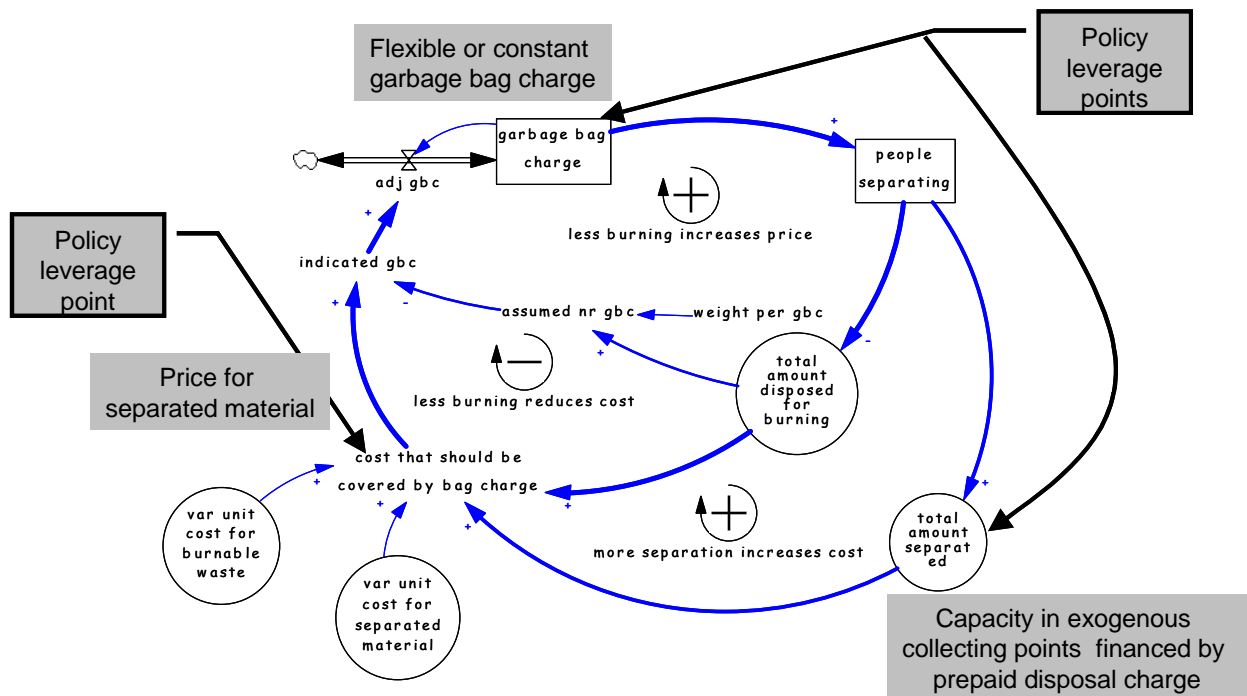
Figure 5.20: Policy-leverage points in the simplified model structure

Four experiments under a prepaid tax regime will be conducted. The object of these experiments is to gain a better understanding about conditions that will lead to a robust intended policy outcome.

1. The implementation of prepaid tax without a garbage bag charge for burnable material (**Implement prepaid tax without garbage bag charge**)

2. The implementation of prepaid tax with a flexible garbage bag charge (**Implement prepaid tax with flexible garbage bag charge)**: In this experiment the garbage bag charge will vary since a zero profit/deficit budget is aimed for.

3. The implementation of a prepaid tax with a constant garbage charge (**Implement prepaid tax with constant garbage bag charge**)

4. The implementation of prepaid tax combined with a constant garbage bag charge and a further increase in the number of recycling streams (**Implement prepaid tax with constant GBC and increase number recycling streams**)

The second policy regime - pricing the separated material - mimics free market conditions, in which citizens have to pay a market price for both burnable and separated material. Two experiments will be conducted:

5. The implementation of market prices for burning and separated material (**Implement price for burning and separated material**)

6. The implementation of market prices for burning and separated material and a further increase in the number of recycling streams (**Implement price for burning and separated material and increase number recycling streams**)

Policy-experiments four and six in which the <*effective nr recycling streams*> will be increased further after 2004 (see Chart 5.19) are designed in order to test both the effect of an increase in recyclable material on the price development and the effect of an increase in the number of streams on citizens' separation behavior. A further increase of the <*effective nr recycling streams*> from 9 to 14 streams is assumed.

Chart 5.19: Further increase of number recycling streams after 2004.

Chart 5.20 depicts the assumed effect of an increase in <*effective nr recycling streams*> on the recyclable material. A decreasing marginal increase in the recyclable material is assumed. The <*initial number recycling streams*> (in 1987: 5 streams) normalizes the X-axis. For the forecasting time period the model operates in a rather inelastic zone.
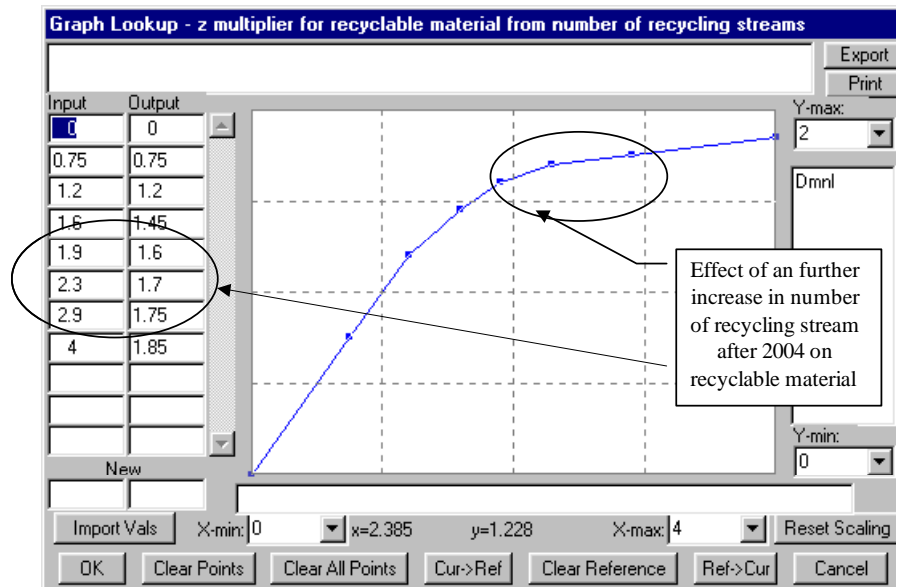
Chart 5.20: Elasticity of recyclable material of a further increase in number recycling streams

Table 5.10 illustrates the design of the six policy-experiments. The active policy-levers (indicated by one) specify the policy bundle for each forecasting experiment.

Names of policy bundles	Policy-lever					
	Garbage bag charge exogenous	Garbage bag charge endogenous	Increase in number streams	Prepaid tax	Increase recycling streams further after 2004	Price for separated material
Forecasting						
Implement prepaid tax without garbage bag charge	0	0	1	1	0	0
Implement prepaid tax with flexible garbage bag charge	0	1	1	1	0	0
Implement prepaid tax with constant garbage bag charge	1	0	1	1	0	0
Implement prepaid tax with constant GBC and increase number recycling streams	1	0	1	1	1	0
Implement price for burning and separated material	0	1	1	0	0	1
Implement price for burning and separated material and increase number recycling streams	0	1	1	0	1	1

Table 5.10: Overview and design of the forecasting policy-experiments. The same logic can be found in the forecasting interface of the model (see Appendix A1).

Implement prepaid tax without garbage bag charge

The policy-experiment **implement prepaid tax without garbage bag charge** has mainly an illustrative character in order to understand the feature of a prepaid tax.

Charts 5.21 A-D illustrate the change in the policy regime after 2003. The strong decline in the <*fraction separated*> (A) after 2003 is a consequence of the missing financial incentive resulting in a strong decline in <*ep willing to separate*> (B). The <*fraction separated*> seeks equilibrium at nearly the same level as in the beginning of the analyzed time horizon (around 26%). In contrast to the initial situation with 4975 <ep willing to separate>, nearly all people get disappointed resulting in only 1436 willing people in 2020. However, the total amount inappropriately separated drops immediately to zero (C). Furthermore, due to the missing garbage bag charge it is quite reasonable that this policy-experiment is not able to balance the budget without an increase in normal taxes (D).

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : Impl p tax wo b charge	1 1 1 Dmnl
three median smooth fraction separated : Impl p tax wo b charge	2 2 2 Dmnl
fraction for burning : Impl p tax wo b charge	3 3 3 3 3 3 Dmnl
fraction separated : Impl p tax wo b charge	4 4 4 4 4 Dmnl

(A)

MOVING PEOPLE

ep willing to separate : Impl p tax wo b charge	1 1 1 1 1 people
iep willing to separate : Impl p tax wo b charge	2 2 2 2 2 2 people
iep not willing to separate : Impl p tax wo b charge	3 3 3 3 3 people
ep not willing to separate : Impl p tax wo b charge	4 4 4 4 4 people

(B)

PRICE AND BUDGET

garbage bag charge : Impl p tax wo b charge	1 1 1 1 Dollars/bag
garbage bag charge exogenous : Impl p tax wo b charge	2 2 2 Dollars/bag
price separation : Impl p tax wo b charge	3 3 3 3 Dollars/kg
profit solid waste management : Impl p tax wo b charge	4 4 4 Dollars/years
non profit threshold : Impl p tax wo b charge	5 5 5 Dollars/years

(C)

WASTE SEPARATED

total amount appropriately separated : Impl p tax wo b charge	—1——1—	kg/year
total amount recyclable material : Impl p tax wo b charge	—2——2——2—	kg/year
tot amount inappropriately separated : Impl p tax wo b charge	—3——3——3—	kg/year

(D)

Charts 5.21 A-D: Dynamics of forecasting policy-experiment "implement prepaid tax without garbage bag charge"

Implement prepaid tax with flexible garbage bag charge

The intended effect of the prepaid tax policy is to disburden the municipality from the rising cost of solid waste management. However, Charts 5.22 A-D show both the intended effect of the prepaid tax policy and the unintended consequences. As a consequence of shifting the separating cost to other actors, the solid waste management cost and *<garbage bag charge>* decline (line 1 in D). The strong decline in the *<garbage bag charge>* results in both less *<ep willing to separate>* - this population drops down to 4138 people (B) - and a decline in the *<fraction separated>*, concluding at 37% (A). A somewhat unexpected result is the strong increase in the *<tot amount inappropriately separated>*. Obviously, due to the remaining cost for burning, the growing number of *<iep not willing to separate>* will continue to put burnable material in the recycling streams in order to save money. However, with this policy-package the municipality will be able to reach a balanced solid waste management budget (D).

REFERENCE FRACTION SEPARATED
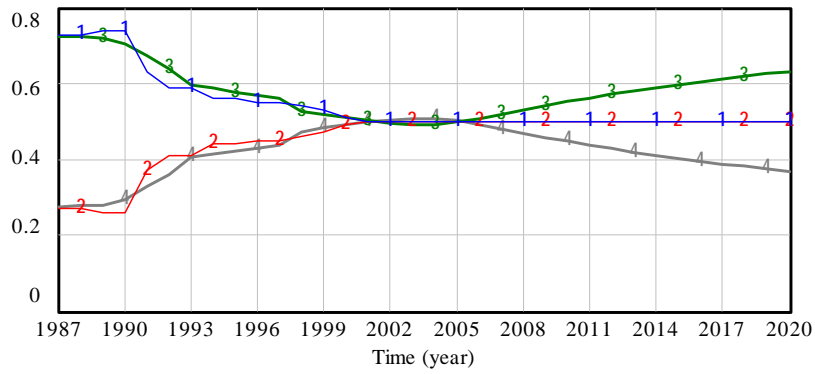
three median smooth fraction burned : Impl p tax w flexible bc	1 1 1	Dmnl
three median smooth fraction separated : Impl p tax w flexible bc	2 2 2	Dmnl
fraction for burning : Impl p tax w flexible bc	3 3 3 3 3 3	Dmnl
fraction separated : Impl p tax w flexible bc	4 4 4 4 4	Dmnl

(A)

MOVING PEOPLE
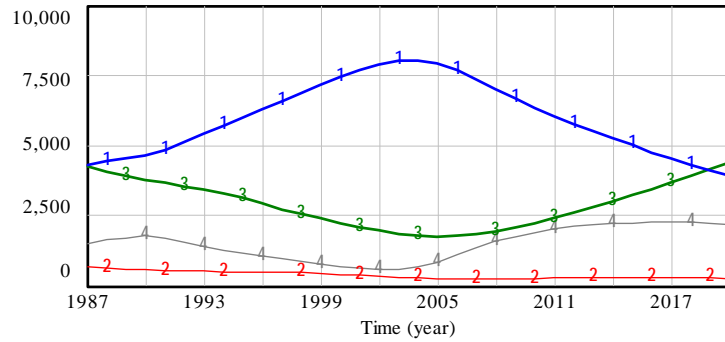
ep willing to separate : Impl p tax w flexible bc	1 1 1 1 1	people
iep willing to separate : Impl p tax w flexible bc	2 2 2 2 2 2	people
iep not willing to separate : Impl p tax w flexible bc	3 3 3 3 3	people
ep not willing to separate : Impl p tax w flexible bc	4 4 4 4 4	people

(B)

WASTE SEPARATED
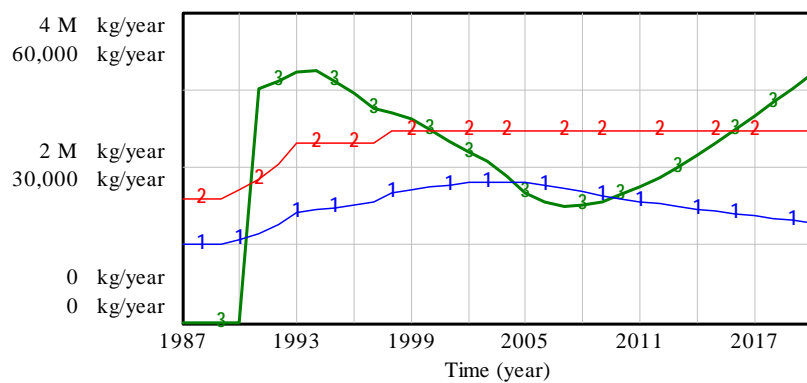
total amount appropriately separated : Impl p tax w flexible bc	1 1	kg/year
total amount recyclable material : Impl p tax w flexible bc	2 2 2	kg/year
tot amount inappropriately separated : Impl p tax w flexible bc	3 3 3	kg/year

(C)

PRICE AND BUDGET
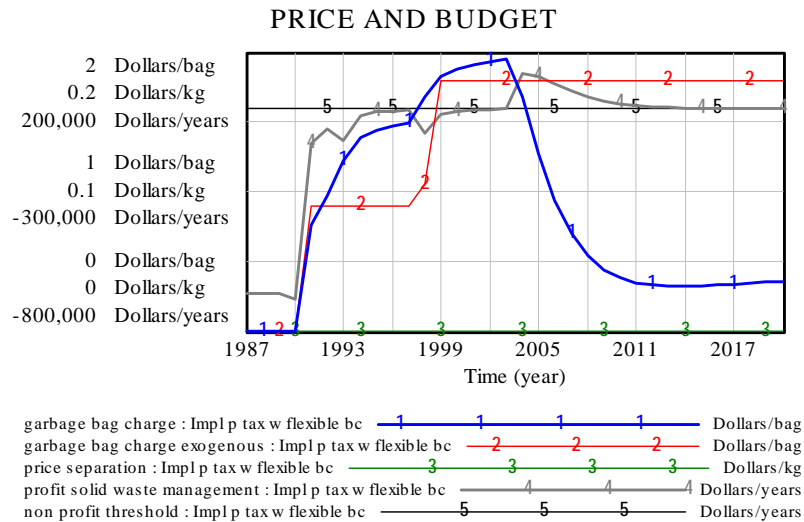
(D)

Charts 5.22 A-D: Dynamics of forecasting policy-experiment "implement prepaid tax with a flexible garbage bag charge"

Implement prepaid tax with constant garbage bag charge

This policy-experiment responds to the observations made in the previous experiments. Obviously, the prepaid tax policy alone has no power to motivate people to separate their waste. Contrarily, countervailing price effects will disappoint them (due to the two reinforcing feedback loops **"getting motivated"** and **"getting disappointed")**. Therefore, this experiment analyses the effect of a prepaid tax in combination with a constant garbage bag charge. In the model the real data of the garbage bag charge are used and held constant after 2000 (see D line 2 <*garbage bag charge exogenous*>). Charts 5.23 A-D illustrate behavior patterns similar to the ones of **inertia policy** in the back-casting experiments. The <*fraction separated*> seeks equilibrium at 54% (A) and about 9100 people are participating in the recycling initiative (B). The same overshoot and decline pattern in the amount of <*tot amount inappropriately separated*> material can be observed. The two peaks are a result of the implementation of and increase in the <*garbage bag charge exogenous*>) in 1991 and 2000 (C). However, an important difference in the solid waste management budget can be observed. Due to the constant garbage bag charge and the shift of recycling cost to other actors, the solid waste management budget exhibits a profit, seeking equilibrium smoothly at 814'000 CHF/year (see D line 4 <*profit solid waste management*>).

REFERENCE FRACTION SEPARATED
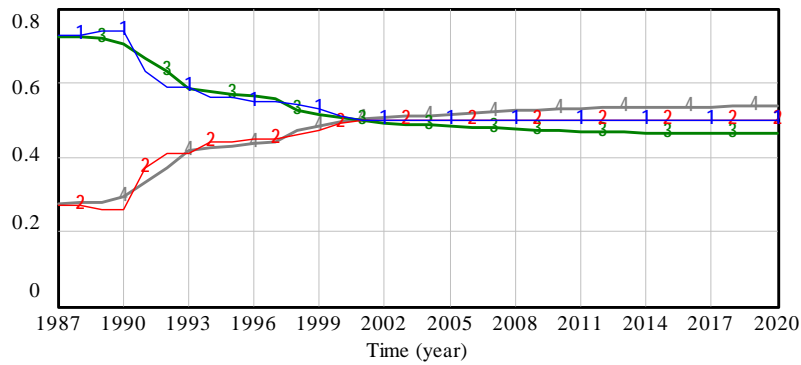
three median smooth fraction burned : Impl p tax w constant bc — 1 1 1 — Dmnl
three median smooth fraction separated : Impl p tax w constant bc — 2 2 2 — Dmnl
fraction for burning : Impl p tax w constant bc — 3 3 3 3 3 3 — Dmnl
fraction separated : Impl p tax w constant bc — 4 4 4 4 4 — Dmnl

(A)

MOVING PEOPLE
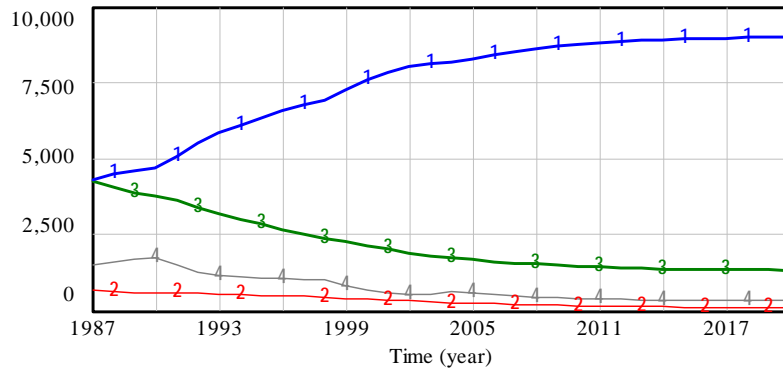
ep willing to separate : Impl p tax w constant bc — 1 1 1 1 1 — people
iep willing to separate : Impl p tax w constant bc — 2 2 2 2 2 — people
iep not willing to separate : Impl p tax w constant bc — 3 3 3 3 3 — people
ep not willing to separate : Impl p tax w constant bc — 4 4 4 4 — people

(B)

WASTE SEPARATED
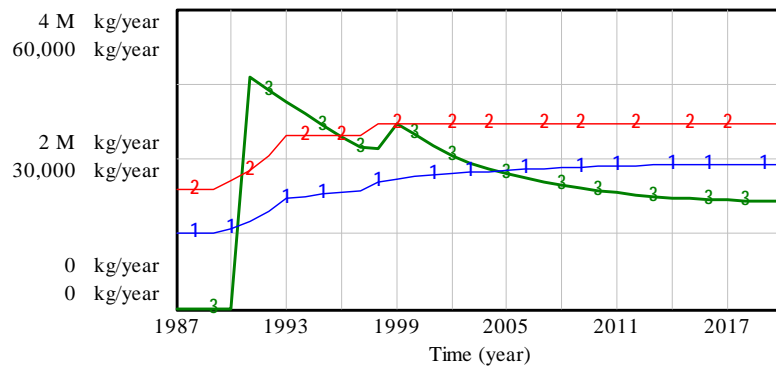
total amount appropriately separated : Impl p tax w constant bc — 1 1 — kg/year
total amount recyclable material : Impl p tax w constant bc — 2 2 2 — kg/year
tot amount inappropriately separated : Impl p tax w constant bc — 3 3 3 — kg/year

(C)

PRICE AND BUDGET
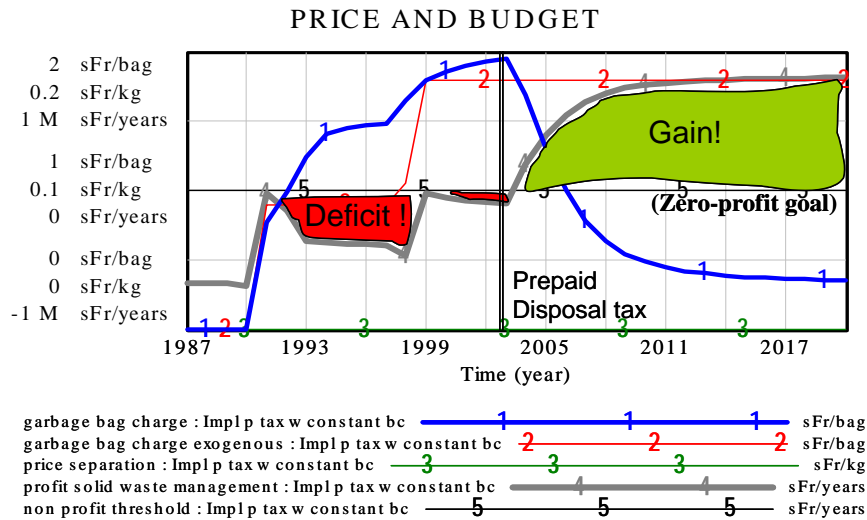
(D)

Charts 5.23 A-D: Dynamics of forecasting policy-experiment "implement prepaid tax with a constant garbage bag charge"

Implement prepaid tax with constant garbage bag charge and increase number recycling streams further

In the previous experiment the recycling initiative takes off but the actual *<fraction separated>* gets limited mainly because of the limited *<total amount recyclable material>*. One way to increase this amount would be to increase the *<effective nr recycling streams>* further, reflecting a situation in which a greater variety of different material becomes recyclable. In fact, this would imitate a scenario in which the recycling market starts to grow with new recycling technologies entering the recycling market.

Charts 5.24 A-D illustrate that in the short term, there is a slight improvement in the fraction separated. It peaks with about 55% in 2009 and then decreases, reaching a value of 52% at the end of the simulation horizon (A). The decline in the *<fraction separated>* is caused by the decrease of willing people. This overshoot and decline pattern reflects the capacity limit of citizens to separate. They get overwhelmed from the separating tasks. As the *<effective nr recycling streams>* increase the *<effect of time cost separating>* weaken the loop **"getting motivated"** resulting in a shift in the loop dominance towards the loop **"getting disappointed"** (B). A further unintended effect can be observed in Chart 5.24 C. After the "first-worse-before-better" pattern of impurity in the first half of the time horizon, a clear growth in the amount of inappropriately separated material can be observed. In addition, Chart 5.24 D clearly exhibits a growing profit (gap between line 4 and five), a further unintended effect of this policy-experiment that has to be considered well in reality.

We can conclude that the efforts to increase the *<total amount recyclable material>* further on, has to be paid by a high price but resulting in an actually small increase in the *<total*

amount appropriately separate> (C) and in worsening the performance of the recycling initiative with respect to impurity.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : pr tax & c gbc & more streams	Dmnl
three median smooth fraction separated : pr tax & c gbc & more streams	Dmnl
fraction for burning : pr tax & c gbc & more streams	Dmnl
fraction separated : pr tax & c gbc & more streams	Dmnl

(A)

MOVING PEOPLE

ep willing to separate : pr tax & c gbc & more streams	people
iep willing to separate : pr tax & c gbc & more streams	people
iep not willing to separate : pr tax & c gbc & more streams	people
ep not willing to separate : pr tax & c gbc & more streams	people

(B)

WASTE SEPARATED

total amount appropriately separated : pr tax & c gbc & more streams —1— kg/year
total amount recyclable material : pr tax & c gbc & more streams —2— kg/year
tot amount inappropriately separated : pr tax & c gbc & more streams —3— kg/year

(C)

PRICE AND BUDGET

garbage bag charge : pr tax & c gbc & more streams —1— Dollars/bag
garbage bag charge exogenous : pr tax & c gbc & more streams —2— Dollars/bag
price separation : pr tax & c gbc & more streams —3— Dollars/kg
profit solid waste management : pr tax & c gbc & more streams —4— Dollars/years
non profit threshold : pr tax & c gbc & more streams —5— Dollars/years

(D)

Charts 5.24 A-D: Dynamics of forecasting policy-experiment "implement prepaid tax with constant garbage bag charge and increase in number recycling streams".

Table 5.11 compares the different price incentives given in the back- and forecasting policy-experiments. Only in the policy-experiment **implement prepaid tax with flexible garbage bag charge** the price is computed endogenously, under the prepaid policy regime. Therefore, a zero profit budget was accomplished only in this policy combination. In the three others forecasting experiments there was either a budget deficit **(implement prepaid tax without garbage bag charge**) or a profit (in the other two cases with constant garbage bag charges).

Garbage bag charge, CHF/bag (Price burning CHF/kg)	1987	1991	2000	2004	2020
Back-casting policy-experiment					

Inertia policy 1	0	0.9	1.8	1.8	1.8
Inertia policy 2	0	0.76	1,87	1,98	2.07
Garbage bag charge policy	0	0.68	0.87	0.87	0.87
Increase nr recycling streams	0	0	0	0	0
Ignorance policy	0	0	0	0	0

Forecasting policy-experiment					
Implement prepaid tax without garbage bag charge	0	0.76	1.87	0.26	0
Implement prepaid tax with flexible garbage bag charge	0	0.76	1.87	1.68	0.36
Implement prepaid tax with constant garbage bag charge	0	0.9	1.8	1.8	1.8
Implement prepaid tax with constant garbage bag charge and increase in number recycling streams	0	0.9	1.8	1.8	1.8
Prepaid tax (CHF/kg)	0	0	0	0.2	0.2
Price separation (CHF/kg)	0	0	0	0	0

Table 5.11: Price incentives given in the different prepaid policy-experiments.

Implement price for burning and separated material

The following two policy-experiments have different objectives: Firstly, they reflect the model behavior under a free market condition, responding to the polluter pay principles. Secondly, they should help enhance the current policy discussion of solid waste management beyond the current prepaid tax discussion. In doing so, solid waste management objectives other than those promoting separation behavior such as giving incentives to diminish the overall material consumptions can be addressed. Finally these policy-experiments also illustrate the limitations of the current model structure, since it capture only the main pressures influencing separation behavior and not an overall waste generation and disposal behavior. The underlying assumptions and the given boundary of the model have to be considered for interpreting the following simulation result.

In spite of these limitations some important insights can be gained. Charts 5.25 A-D primarily reflect the weakening effect of separating cost on the loop **"getting motivated"** that leads to a shift in the loop dominance to **"getting disappointed"** (B). This shift results in a strong decline in the *<fraction separated>* (A). At the end of the time horizon of the simulation run only 1'838 people are willing to separate and only 28% of the overall waste was separated. In contrast to these disappointing results, Chart 5.25 C shows the strength of this policy approach. The amount inappropriately separated drops immediately to zero when the new policy gets implemented in 2003. Furthermore, Chart 5.25 D illustrates that in this policy-experiment the goal of a zero profit budget can be met and the prices for burning and separating seem to approach equilibrium at a lower level.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : Price f burn and separ ——1——1——1——1—— Dmnl
three median smooth fraction separated : Price f burn and separ ——2——2——2—— Dmnl
fraction for burning : Price f burn and separ ——3——3——3——3——3——3—— Dmnl
fraction separated : Price f burn and separ ——4——4——4——4——4——4—— Dmnl

(A)

MOVING PEOPLE

ep willing to separate : Price f burn and separ ——1——1——1——1——1—— people
iep willing to separate : Price f burn and separ ——2——2——2——2——2——2—— people
iep not willing to separate : Price f burn and separ ——3——3——3——3——3—— people
ep not willing to separate : Price f burn and separ ——4——4——4——4——4—— people

(B)

WASTE SEPARATED

total amount appropriately separated : Price f burn and separ ——1——1—— kg/year
total amount recyclable material : Price f burn and separ ——2——2——2——2—— kg/year
tot amount inappropriately separated : Price f burn and separ ——3——3——3—— kg/year

(C)

(D)

Charts 5.25 A-D: Dynamics of forecasting policy-experiment "implement price for burning and separated material".

Implement price for burning and separated material and increase number recycling streams further

In this policy-experiment the *<effective nr recycling streams>* will be increased further, in addition to pricing separating and burning.

Charts 5.26 A-D mainly portray the same behavior patterns as in the former experiment. However, an important difference can be observed. A closer glance at Chart 5.26 B reveals a stronger decline in *<ep willing to separate>*. The increase in *<effective nr recycling streams>* overwhelms people, resulting in an even weaker **"getting motivated"** than in the previous experiment resulting in a smaller number *<ep willing to separate>* (1 458 people), (A). The slight increase in the *<total amount recyclable material>* (C) is compensated by the countervailing effect of separating time cost, resulting in a low *<fraction separated>* of 28%. Chart 5.26 D shows an increase in the *<price separation>* caused by the *<effect of number recycling streams on recycling unit cost>*.

REFERENCE FRACTION SEPARATED

three median smooth fraction burned : Price f burn and separ & more streams — 1 — 1 — Dmnl
three median smooth fraction separated : Price f burn and separ & more streams — 2 — 2 — Dmnl
fraction for burning : Price f burn and separ & more streams — 3 — 3 — 3 — 3 — Dmnl
fraction separated : Price f burn and separ & more streams — 4 — 4 — 4 — 4 — Dmnl

(A)

MOVING PEOPLE

ep willing to separate : Price f burn and separate & more streams — 1 — 1 — 1 — people
iep willing to separate : Price f burn and separate & more streams — 2 — 2 — 2 — 2 — people
iep not willing to separate : Price f burn and separate & more streams — 3 — 3 — 3 — people
ep not willing to separate : Price f burn and separate & more streams — 4 — 4 — 4 — people

(B)

WASTE SEPARATED

total amount appropriately separated : Price f burn and separ & more streams   kg/year
total amount recyclable material : Price f burn and separ & more streams — 2 — kg/year
tot amount inappropriately separated : Price f burn and separ & more streams   kg/year

(C)

(D)

Charts 5.26 A-D: Dynamics of forecasting policy-experiment "implement price for burning and separated material and increase number of recycling streams".

The following Table 5.12 compares the development of the prices for burning and separating. In both experiments, the prices for burning are nearly the same (around 0.13 CHF/kg). Furthermore, those prices are lower than the price for separating at the end of the time horizon. In the policy-experiments with a further increase in <*effective nr recycling streams*>, the <*price separation*> grows even higher up to 0.80 CHF/kg whereas without a further increase, it will find equilibrium at around 0.53 CHF/kg.

Market price regime	1987	1991	2000	2004	2020
Price burning (CHF/kg)					
Implement price for burning and separated material	0	0.25	0.62	0.12	0.12
Implement price for burning and separated material and increase number recycling streams	0	0.25	0.62	0.16	0.13
Price separation (CHF/kg)					
Implement price for burning and separated material	0	0	0	0.58	0.53
Implement price for burning and separated material and increase number recycling streams	0	0	0	0.60	0.80

Table 5.12: Comparison development market prices under a market price regime.

Comparing the prices with the price incentives given in the prepaid tax experiment, shows that the policy-package **implement prepaid tax with flexible garbage bag charge** results in similar prices for burning as in the market price experiments (compare the darkened cells in Table 5.12 and 5.13).

Prepaid tax regime	1987	1991	2000	2004	2020
Price burning (CHF/kg)					
Implement prepaid tax without garbage bag charge	0	0.25	0.62	0.08	0
Implement prepaid tax with flexible garbage bag charge	0	0.25	0.62	0.56	0.12
Implement prepaid tax with constant garbage bag charge	0	0.3	0.6	0.6	0.6
Implement prepaid tax with constant garbage bag charge and increase in number recycling streams	0	0.3	0.6	0.6	0.6
Prepaid tax (CHF/kg)	0	0	0	0.2	0.2
Price separation (CHF/kg)	0	0	0	0	0

Table 5.13: Comparison development garbage bag charge under a prepaid tax regime.

At this point it is important to be aware of the danger of misinterpreting the data. The aim of the table is to compare the trend in prices under the different policy-packages and not to obtain an exact forecast of the price at a specific time.

5.6.4   Insights from the forecasting experiments

The main observed characteristic of a **prepaid tax policy** is that it tends to reinforce the loop **"getting disappointed"** due to mainly two effects: Firstly, due to the countervailing price effect, and secondly due to a crowding effect. In the case of a combination with a garbage bag charge meeting a zero profit goal, the adjusted garbage bag charge may be too low to hinder people getting disappointed to separate. The prepaid tax by itself would give no systematic incentive to generate impurity. Combining it with a garbage bag charge may lead to higher impurity, since more people become unwilling to separate correctly.

Combining a prepaid tax policy with a constant garbage bag charge policy is nearly as effective as the inertia policy 2. Furthermore, this policy-package would result in a profit given a constant solid waste generation. The dynamics of the countervailing price effect of the prepaid tax policy with constant garbage bag charge lead to *a trade off between the policy effectiveness and a zero profit budget*. Whereas an effective policy, with flexible garbage bag charges tends to lead to a zero profit budget or a deficit, a sub optimal policy with a lower *<fraction separated>* tends to lead to a profit. This trade-off could make a recycling initiative economically questionable for local authorities.

Another important observation is that an additional increase in the *<effective nr recycling streams>* would overwhelm the citizens resulting in a lower *<fraction separated>* and higher impurity. The hypothesized crowding effect is not very influential at this point since the pool of *<ep willing to separate>* is already nearly depleted due to the dominance of the loop **"getting disappointed".** The crowding effect underlines this trend (see also Chart 5.41).

The policy-package **implement price for burning and separated material** results in the worst outcome with respect to the *<fraction separated>* due to a double price effect. Firstly, the *<garbage bag charge>* decreases resulting in more people getting disappointed. Secondly, the higher separation cost impedes people getting motivated. In the case of a further increase in the *<effective nr recycling streams>* even fewer people get motivated due to a further raise in both time and separating cost. However, a zero profit goal can be met and this policy-package would improve the quality of separated material.

Table 5.14 compares the results of the policy-experiments. The values of the variables of interest indicate the overall policy performance at the end of the time horizon. The <*fraction separated*> illustrates that a comparable policy outcome could be reached under both the **inertia policy 2** and the policy-package **implement prepaid tax policy with constant garbage bag charge**. However, the variable <*accumulated cost for local waste management*> illustrates that under the prepaid charge policy the cost of the public solid waste management will be lower. All the policies giving price incentives tend to cause some impurity in the recycling streams unless both waste qualities would be priced. The policy-package **implement prepaid tax with constant garbage bag charge** is effective and results in lower cost. This gives evidence that this policy-package could outperform the actual **inertia policy 2** – if the cost for municipalities becomes a critical factor.

	Fraction separated (%)	People willing to separate (People)	Accumulated fraction impurity (Dmnl)	Accumulated cost for local waste management (CHF)
Back-casting policy-experiment				
Inertia policy 2	54	9200	0.56	51.5M
Garbage bag charge policy	33	8043	0.68	39.5M
Increase nr recycling streams	25	1133	0	45.0M
Ignorance policy	28	5324	0	38.5M
Forecasting policy-experiment				
Implement prepaid tax without garbage bag charge	26	1436	0.35	38.4M
Implement prepaid tax with flexible garbage bag charge	37	4138	0.69	37.9M
Implement prepaid tax with constant garbage bag charge	54	9084	0.52	37.6M
Implement prepaid tax with constant garbage bag charge and further increase in number recycling streams	52	6956	0.6	38.1M
Implement price for burning and separated material	28	1838	0.35	48.4
Implement price for burning and separated material and increase number recycling streams	28	1458	0.35	52.3

Table 5.14: Comparison of system indicators in the back- and forecasting policy-experiments.

5.6.5 Sensitivity Analysis

In this section the effect of uncertainty in model assumptions on policy conclusions will be tested with different sensitivity analyses. These tests assess the robustness of policy implications that can be drawn from the model output. The basic idea is to test if the model behaves plausibly under different parameter values, how it changes its behavior patterns and if changes in parameters lead to different policy implications that are implausible.

The model has fifty parameters and thirty-three non-linear functions. A complete list and a short description of the parameters and graphical functions can be found in Appendix A3. For some parameters empirical data were available. But most parameters and all non-linear functions are modeler defined and calibrated to real data of the reference mode. All the assumptions are numerically sensitive, but only few assumptions seem to exhibit a behavior mode sensitivity or policy sensitivity[67]. Since the purpose of the model is to get insights about patterns of behavior, there is no great concern about the exact point estimation of output variables. The purpose of the model is not to predict exact values but to understand the influence of different policy-packages on behavior patterns. Therefore, the focus is on policy sensitivity. Only those parameters will be tested that are both highly uncertain in their nature of sensitivity and likely to be influential.

An additional objective of sensitivity testing is to find the most influential parameters. This would be the best intervention points for effective policies.

The tipping point and behavior mode and policy sensitivity

As mentioned in the beginning of Chapter 5.6 (Model behavior and policy-experiments), system behavior is strongly determined by the two positive feedback loops **"getting disappointed"** or **"getting motivated"** (see Figure 5.20). The strength of the loops is determined either by the "fraction becoming willing" or the "fraction becoming unwilling". If the <*fraction becoming willing*> gets stronger than the <*fraction becoming unwilling*> the model exhibits s-shaped growth otherwise it exhibits s-shaped decay. Therefore, some small changes in parameters could change a growth-trend to a decay behavior.

Such a critical parameter value is called tipping point. If parameter values operate near a tipping point, the implications drawn from a policy-experiment become weak. In the previous policy-experiment we have seen that the implementation of new policies in 2003 could change the system behavior causing the <*fraction separated*> to fall (i.e. **implement prepaid tax without garbage bag charge**). To assess the robustness of these results, we have to test if the uncertainty in parameters would lead to other policy-experiment results. Furthermore, it may be useful to know the value of where the behavior bifurcates. These sensitive points may be important policy leverages, since a minor change in the parameter

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[67] „Behavior mode sensitivity exists when a change in assumption changes the patterns of behavior generated by the model. … Policy sensitivity exists when a change in assumption reverse the impacts or desirability of a proposed policy" (Sterman 2000:883).

could lead to a crucial change in the systems behavior, determining the success or failure of a policy initiative.
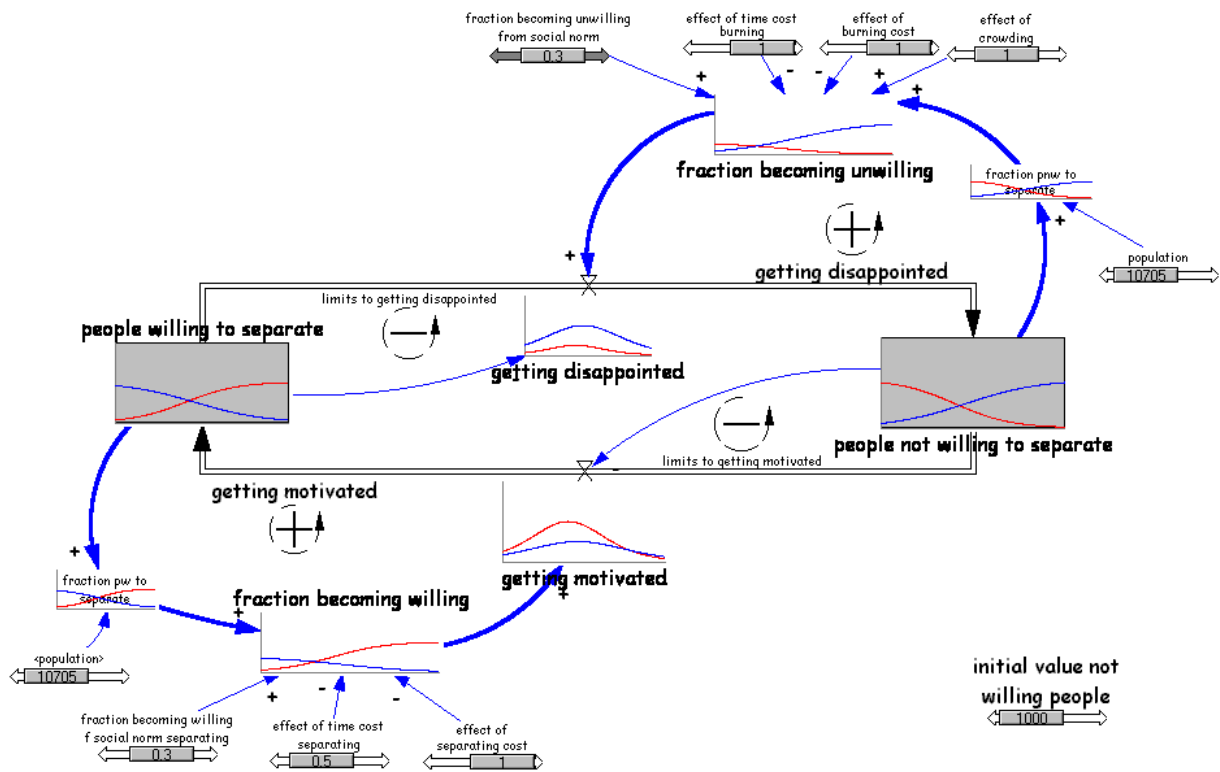
Figure 5.20: A simplified recycling diffusion model determining the success or failure of a recycling initiative.

All the parameters and graphical functions influencing either the <*fraction becoming willing*> respectively the <*fraction becoming unwilling*> can change the behavior of the model. It is likely that all those parameters are also policy sensitive since this model structure mainly determines the dynamics of the system and the outcome of policy-experiments.

However, important parameters are those that are uncertain, for example the <*initial value nwp*> not willing people or the <*max acceptable separating time*> or those that are highly relevant to political interventions, such as <*normal time per stream*>. In the following paragraph the three most important parameters will be tested. The main characteristics of the test results can be transferred to other similar parameters.

Sensitivity test A: Initial value not willing people

In the current SD-SWM-model the <*perceived social norm separating*> is determined by the fraction of <*ep willing to separate*>. The social norm also influences other variables such as the <*acceptable time for separating*>. The initial condition of the fraction willing to separate is specified by the parameter <*initial value nwp*>. If there were not other influences, this parameter would determine which loop is dominating the system at the beginning. Hence, the outcome of a recycling initiative is likely to be sensitive to this initial condition. The sensitivity analysis will be conducted under different policies:

- the **inertia policy 2** (with the actual policy – increase in nr recycling streams and garbage bag charge)

- the **ignorance policy** (no increase in nr recycling stream and no garbage bag charge)

- the **garbage bag charge policy**

- the **increase in nr recycling stream policy**

- the **implement prepaid tax with flexible garbage bag charge policy**.

For the sensitivity test the uncertainty range of the *<initial value nwp>* is in the range between 1100 – 9000 people, the actual model value is 5730 people. For the thirty simulation runs the different initial values are uniform randomly chosen within the uncertainty ranges.

Test settings *<initial value nwp>*		
Distribution: random uniform, 30 runs		
Model value: 5730	Minimum value: 1100	Maximal Value: 9000 (people)

Inertia policy 2 (Increase in nr recycling streams and garbage bag charge)

For illustrative purpose, the result of sensitivity testing will be displayed in different formats for one test-experiment. In further tests the most insightful format will be chosen for each test result.

The Charts 5.27 A-C show the sensitivity of the parameter *<initial value nwp>* on the variable *<ep willing to separate>* in three different ways; first, illustrating the confidence bounds of the outcome, then, illustrating the individual traces of each run, and finally the distribution of the outcome at a specific time.

Chart 5.27 A shows the confidence bounds for all the output values of <*ep willing to separate*>. There is a 95% chance that the recycling initiative will take off even under different initial conditions.

Chart 5.27 B shows the sensitivity output in the form of individual simulation traces. Over time, nearly all the traces seek equilibrium. However, there are two individual runs indicating that the policy initiative would not take off. Those runs are characterized through a low <*initial value nwp*>.

Chart 5.27 C illustrates the distribution of values for a variable over all the thirty simulations done at a specific time. In this test the chosen time is 2003. There exists a small probability (about 3 runs out of 30) that only few people (between 1000-2000) would be willing to separate. However, the probability that in 2003 nearly 7000-8000 people would be willing to separate is 27/30%.

The test-results indicate that it is plausible that under the given **inertia policy** characterized by a high financial incentive to separate nearly all people become motivated. Furthermore, a plausible explanation could be given explaining the two outliers with a very low <*initial value nwp*>. The <*initial value nwp*> indicates the actual state of the diffusion

(A)

(B)

(C)
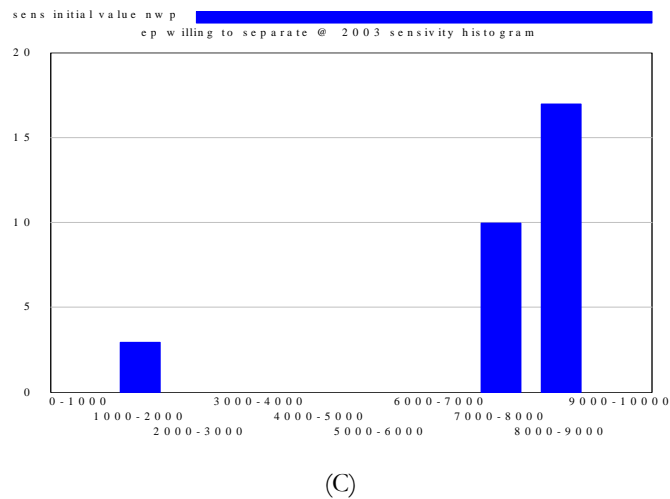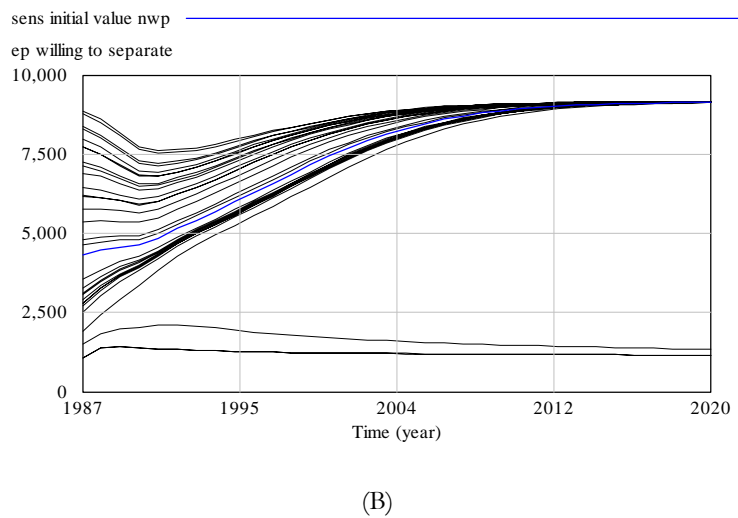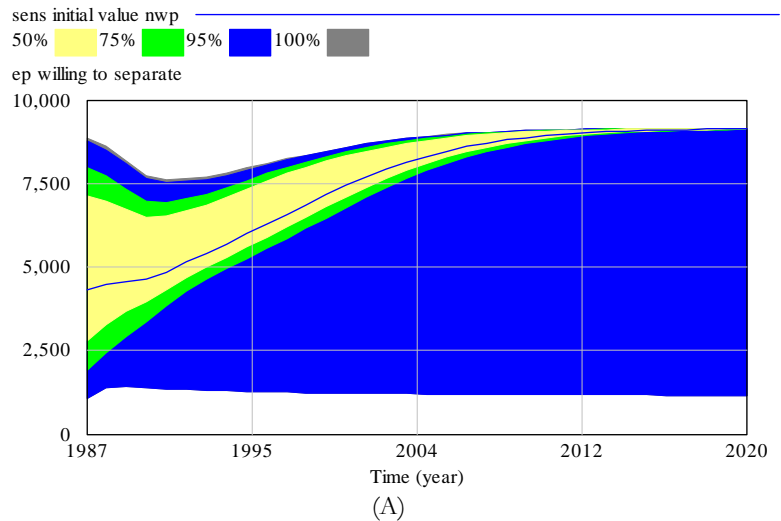
Charts 5.27 A-C: Sensitivity analysis <*initial value nwp*> illustrating different display formats: confidence bounds, individual traces and bar graph

process of the recycling initiative. In a society, in which separating is not debated and in which no model behavior exists it will be harder to motivate people to separate. Therefore, given the time cost for separating, it is plausible that there would be a high separating policy resistance. Actually, those two outliers demonstrate the robustness of the policy implications that can be drawn from the model.

However, the actual number *<ep willing to separate>* is not measured in the real system. Therefore, other relevant policy indicators, such as the *<fraction separated>* or the *<total amount inappropriately separated material>* or the *<garbage bag charge>,* will be used to describe the outcome of the sensitivity test.

Charts 5.28 A-C show the result of the uncertainty in *<initial value nwp>* on those variables. Nearly all the initial conditions end up in a *<fraction separated>* around 50% (A). The confidence bound for the endogenous computed garbage charge is very small (B). Only the variable *<total amount inappropriately separated>* shows a greater variance in the individual traces during the growth phase around 1991 but then nearly all traces seek the same equilibrium (C).

(A)

(B)

sens initial value nwp inertia 2
50%   75%   95%   100%
garbage bag charge
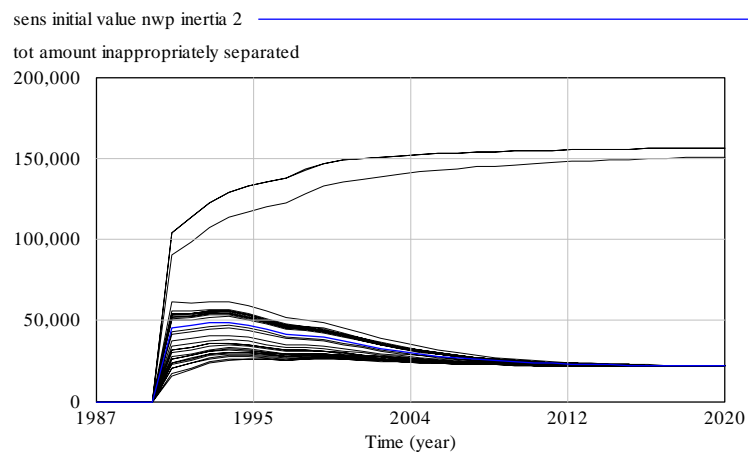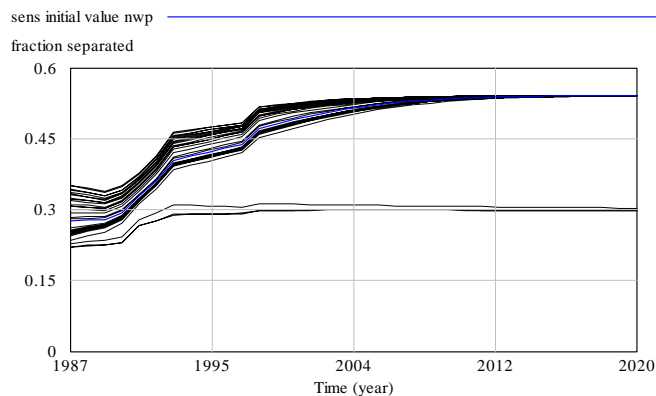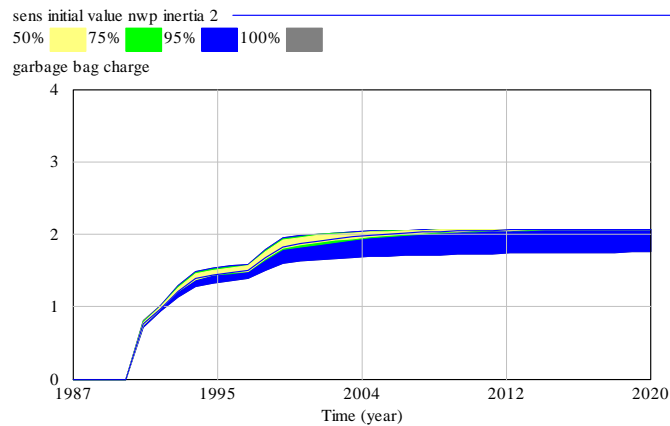
(C)

Charts 5.28 A-C: Sensitivity analysis *<initial value nwp>*with inertia policy 2

All the results give evidence that the model output under the **inertia policy** is not highly sensitive to the uncertainty in *<initial value nwp>*. However, the policy implications will be different in cases where separation behavior is a new issue in the real world than in cases where it is already a topic of public discussion. Contrarily, the smooth adjustment process of a *<garbage bag charge>* that meets a zero budget policy is a robust result in all cases.

Different policy interventions

So far the model exhibits robust sensitivity results in the *<initial value nwp>* under the inertia policy 2. However, the robustness will be tested for different policy-experiments since the purpose of the model is to gain insight about the system behavior under different policy interventions.

- Chart 5.29 A displays the case of a **garbage bag charge policy** (back-casting policy-experiment)

- Chart 5.29 B shows the model behavior under the policy **increase nr recycling streams** (back-casting policy-experiment)

- Chart 5.29 C- illustrates the model behavior under the **ignorance policy** (back-casting policy-experiment).

- Chart 5.29 D illustrates the sensitivity under the policy **implement prepaid tax with flexible garbage bag charge** (fore casting policy-experiment).

Comparing these sensitivity test results with the back- and forecasting policy-experiments gives a somewhat surprising insight. In all cases, the charts exhibit behavior mode sensitivity (we can observe either a growth or decay behavior pattern) but no policy sensitivity. In

Charts 5.29 A-C all the lines converge to equilibrium levels that are comparable with the back-casting policy-experiment results. The large changes in the *<initial value nwp>* yield

narrow confidence bounds towards the end of the simulation run. The model shows path dependence, since it is either dominated by the positive feedback loop **"getting motivated"** or **"getting disappointed".** Chart 5.29 D illustrates clearly that the policy **implement prepaid tax with flexible garbage bag charge** will lead to a shift in the loop dominance as the new policy-package gets implemented. Under the regime of the actual policy the positive loop **"getting motivated"** was dominant whereas under the prepaid charge policy the positive loop **"getting disappointed"** dominates.
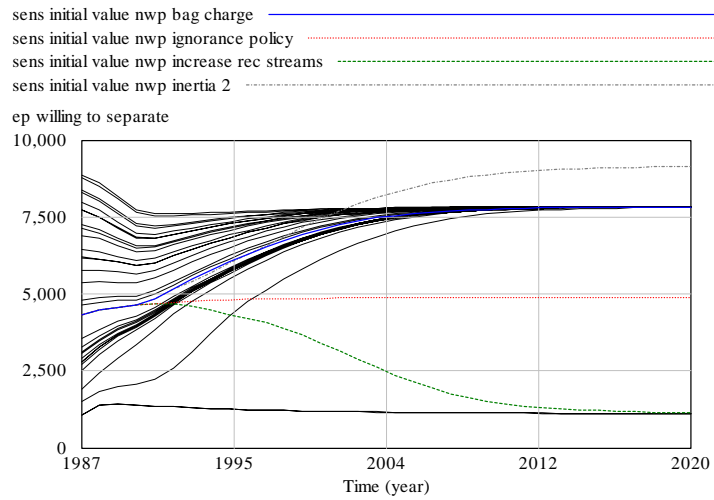
(A) garbage bag charge policy – *<ep willing to separate>*

(B) increase in nr recycling streams policy – *<ep willing to separate>*

sens initial value nwp ignorance policy
sens initial value nwp increase rec streams
sens initial value nwp inertia 2
sens inital value nwp prepaid & b charge

ep willing to separate

(C) ignorance policy – *<ep willing to separate>*

sens inital value nwp prepaid & b charge
sens initial value nwp increase rec streams
sens initial value nwp ignorance policy
sens initial value nwp inertia 2
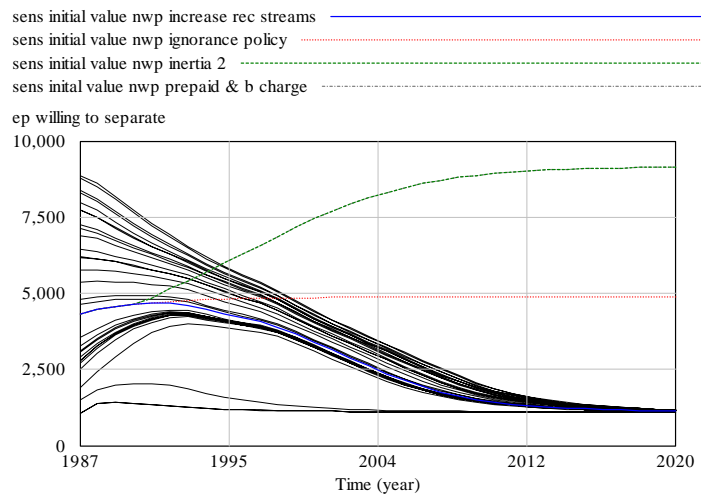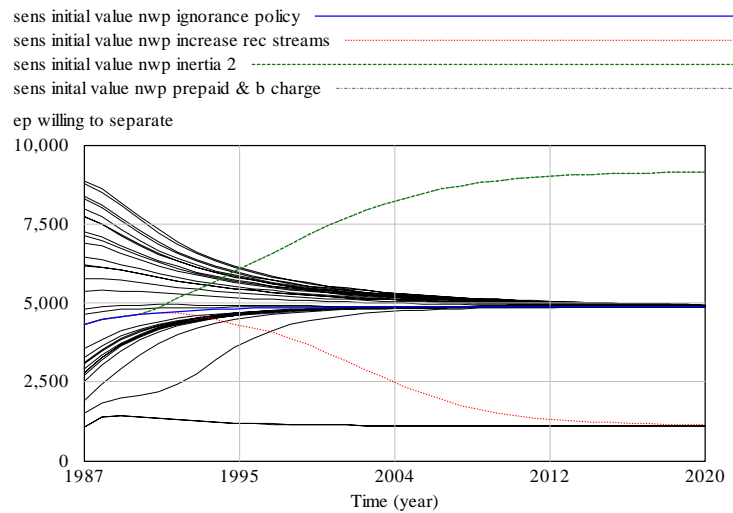
ep willing to separate
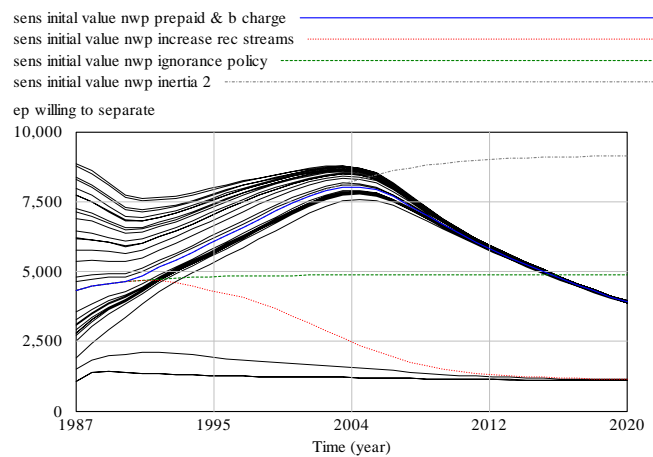
(D) prepaid tax and garbage charge policy - *<ep willing to separate>*

Charts 5.29: Sensitivity analysis <initial value not willing people> with different policy-packages

Sensitivity test B: Max acceptable separating time

The parameter *<max acceptable separating time>* operationalizes an average willingness to spend time on separating. If the time required for separating is higher than the average willingness then the loop **"getting motivated"** will lose some numerical strength. Therefore, the parameter is influential. Furthermore, its real empirical value is unknown, and therefore, in the model it is defined with a high uncertainty by the modeler. For the sensitivity test the uncertainty range in this parameter is specified as follows.

Test settings <max acceptable separating time>		
Distribution: random uniform, 30 runs		
Model value: 2	Minimum value: 1	Maximal Value: 3 (hours/week)

Charts 5.30 A-D illustrate that in this range of uncertainty the model operates near a tipping point. The model shows a behavior mode sensitivity and generates different patterns of behavior ranging from s-shaped growth to overshoot and collapse to a smoothed decline (see Charts 5.30 B, C, D). Comparing these test-outcomes with the **inertia policy 2** - experiment results shows that the parameter *<max acceptable separating time>* exhibits policy sensitivity. The model has two different basins of attraction resulting from a shift in the dominance of the two positive feedback loops. The confidence bounds diminish as the parameter values near the borders of attraction. The behavior bifurcates when *<max acceptable separating time>* falls below 1.65 hours/week (tipping point). The bar graph sensitivity output emphasizes that the most likely outcome in 2003 would be on the upper border of attraction (Chart 5.30 A). The tipping point leads to a wide confidence bound in both the *<fraction separated>* and the *<total amount inappropriately separated>*, whereas the confidence bound for *<garbage bag charge>* stays relatively small (Chart 5.30 E).

Chart 5.30 F illustrates that a smaller uncertainty range - set above the tipping point - yields smaller confidence bounds without any behavior mode sensitivity.

(A) inertia policy2– bar graph distribution of values in 2003*: <ep willing to separate>*
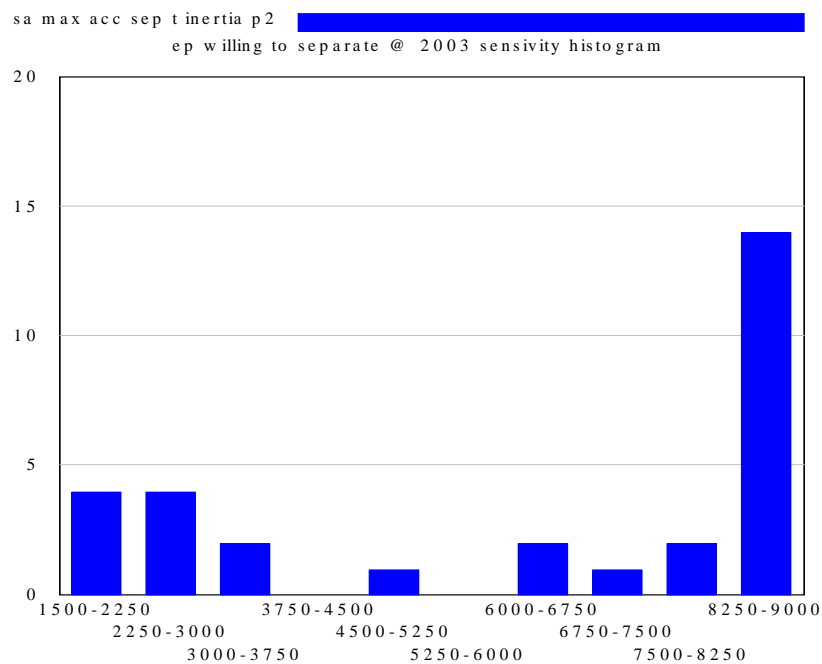
sa max acc sep t inertia p2
ep willing to separate

(B) inertia policy2 – *<ep willing to separate>*

sens max acc sep t inertia p2
fraction separated

(C) inertia policy2 – *<fraction separated>*

sens max acc sep t inertia p2
test1
tot amount inappropriately separated

(D) inertia policy2 – ***<total amount inappropriately separated>***

sa max acc sep t inertia p2 ————————————————————————————

50% [yellow] 75% [green] 95% [blue] 100% [gray]

garbage bag charge

(E) inertia policy2 – *<garbage bag charge>*

test1 ————————————————————————————
sens max acc sep t inertia p2 ···

fraction separated
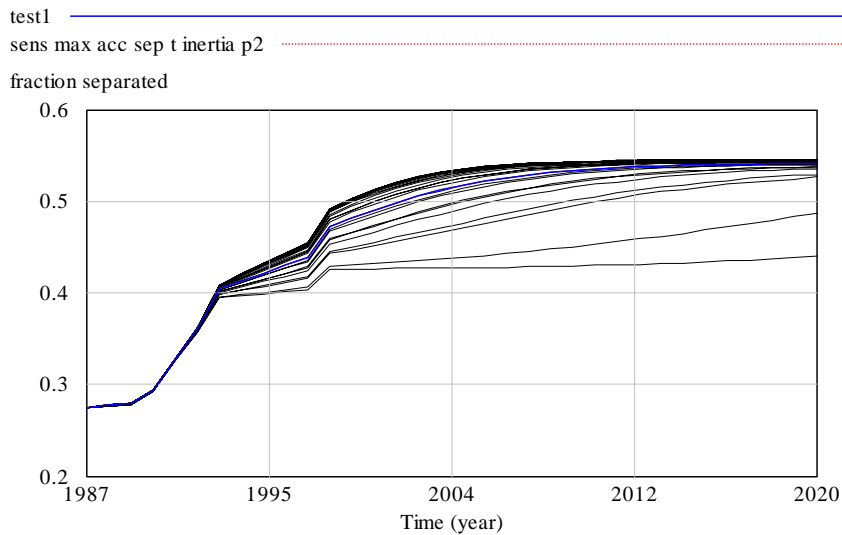
(F) Sensitivity analysis *<max acceptable separating time>* with a **smaller uncertainty range from 1.65 to 3 hours/week**" under inertia policy2 – *<fraction separated>*

Charts 5.30: Sensitivity analysis <max acceptable time> with inertia policy 2.

Sensitivity test C: Normal time per stream

The parameter *<normal time per stream>* is as influential as the parameter *<max acceptable separating time>*. But it is a parameter that can be influenced by policy interventions. Therefore, it is a candidate that could become an important leverage point in the system. For sensitivity analysis the value range is defined as follows:

Test settings *<normal time per stream>*		
Distribution: random uniform, 30 runs		
Model value: 0.2	Minimum value: 0.05	Maximal Value: 0.3 (hours/week)

Charts 5.31 A-E illustrate that the parameter variations yield similar behavior mode sensitivity as the previously discussed parameter. The behavior bifurcates at 0.24 hours/week. If the parameter range is set below this value the model no longer shows behavior mode and policy sensitivity. For all values between 0.05 and 0.24 hours/week the model shows a robust behavior in which the recycling initiative would take off.

sens norm time p stream
ep willing to separate @ 2003 sensivity histogram
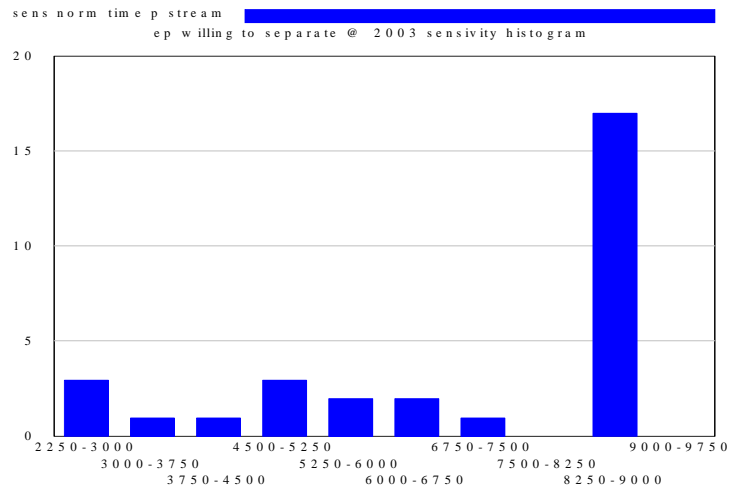
(A) inertia policy2– bar graph distribution of values in 2003: *<ep willing to separate>*

(B): inertia policy2– *<ep willing to separate>*

sens norm time p stream

fraction separated

(C) inertia policy2 – *<fraction separated>*

sens norm time p stream

50% 75% 95% 100%

tot amount inappropriately separated

(D) inertia policy2 – *<total amount inappropriately separated>*

sens norm time p stream

50% 75% 95% 100%

garbage bag charge
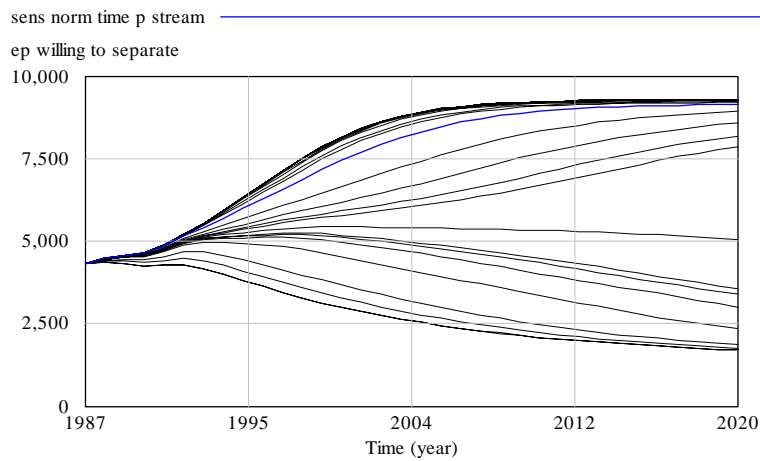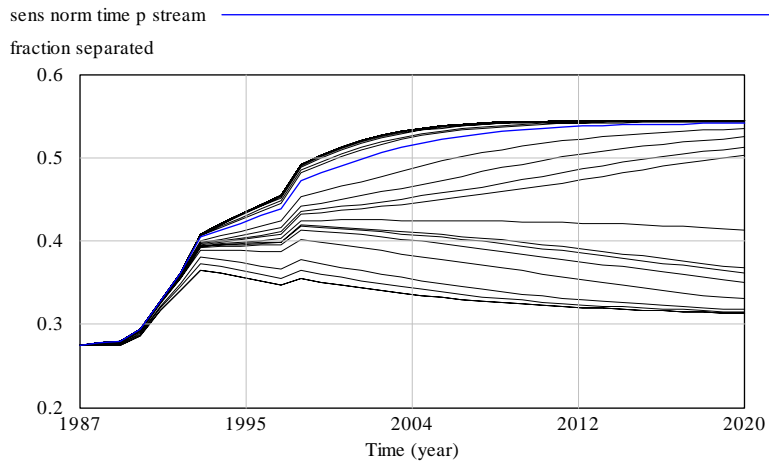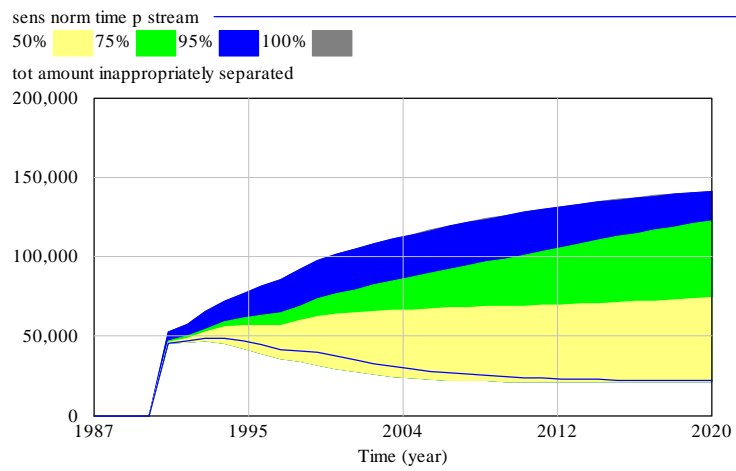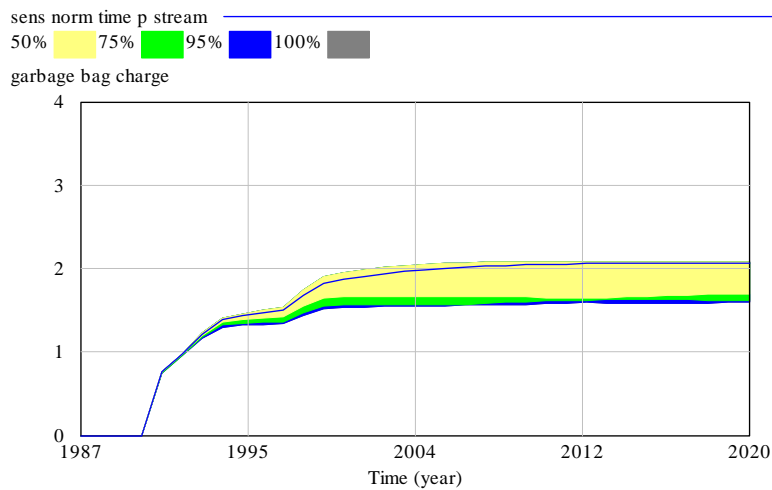
(E) inertia policy2 – *<garbage bag charge>*

(F) Sensitivity analysis <*normal time per stream*> with a **smaller uncertainty range from 0.05 to 0.24 hours/week**" under inertia policy2 – <*fraction separated*>

Charts 5.31 A-F: Sensitivity analysis <normal time per stream> with inertia policy 2.

Multivariate sensitivity test D: Testing the effect of uncertainty in all three parameters

In the previous chapters, the sensitivity to parametric assumptions are analysed in a univariate mode. In this section a multivariate sensitivity analysis is presented. The interactions of the range of uncertainty of the three parameters <*initial value nwp*>, <*max acceptable separating time*>, and <*normal time per stream*> can generate very different confidence bounds, and different individual traces, respectively. The multivariate analysis test is specified as follows:

Test settings for multivariate sensitivity testing

Distribution: random uniform, Multivariate
<*initial value nwp*>
Model value: 5730   Minimum value: 1100   Maximum value: 9000 (people)
<*max acceptable separating time*>
Model value: 2   Minimum value: 1   Maximum value 3 (hours/week)
<*normal time per stream*>
Model value: 0.2   Minimum value: 0.05   Maximum value 0.3 (hours/week)

Charts 5.32 A-D emphasize the power of the two borders of attraction. In addition they illustrate the full range of behavior mode sensitivity exhibited by this model: s-shaped growth, overshoot and decay or only decay behavior pattern. The multivariate analysis also shows that in most parameter-value combinations the positive feedback loop **"getting motivated"** dominates. Moreover, we can observe that the uncertainty in the three analyzed parameters have no remarkable effect on the <*garbage bag charge*> adjustment process (Chart 5.32 D). Furthermore, the charts indicate that in a worst-case scenario (see Chart 5.32 A), when the parameter <*normal time per stream*> is high and if the parameter <*max acceptable*

separating time> is low, the recycling initiative could fail. This is also the case when nearly all the people would be willing to separate in the beginning, which is not a very realistic parameter combination (see the few lines in Chart 5.32 A that starts at a high value *<ep willing to separate>* and decay towards the lower border of attraction).

In spite of these promising test results, the lower border of attraction in Chart 5.32 B raises a question. Is it plausible that in a worst-case scenario the *<fraction separated>* will not fall below 30% under the **inertia policy**? This lower bound is mainly determined by the parameters *<normal fraction separated>* of the different groups of people. They vary from 20% to 38% and are calibrated to the initial condition in 1987, when only five recycling streams were offered and no garbage bag charge was in place. It is likely and plausible that these conditions would determine the lower border in the failure of a new recycling initiative. This means that not more people become willing to separate than under the old recycling-conditions with no price incentives to separate.
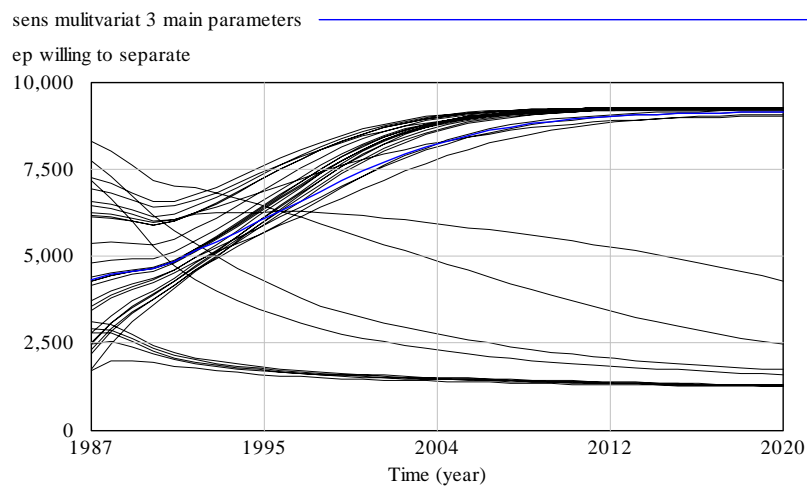
(A) inertia policy 2 – *<ep willing to separate>*

(B) inertia policy 2 – *fraction separated>*

sens mulitvariat 3 main parameters ――――――――――――――――

tot amount inappropriately separated

(C) inertia policy 2 – *<total amount inappropriately separated>*

sens mulitvariat 3 main parameters ――――――――――――――――

garbage bag charge
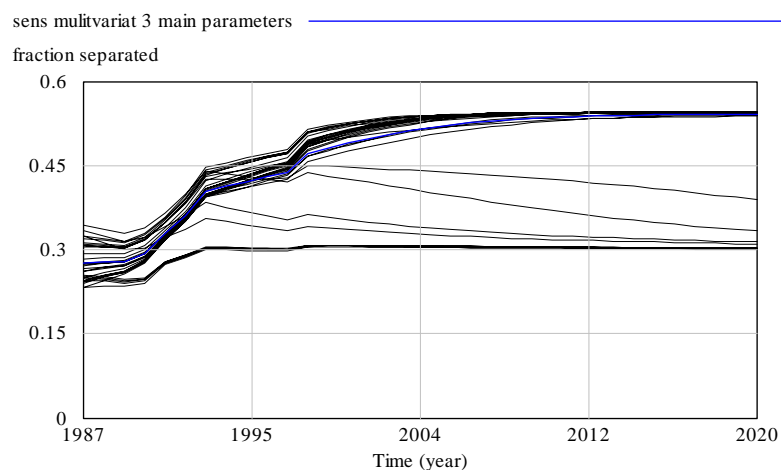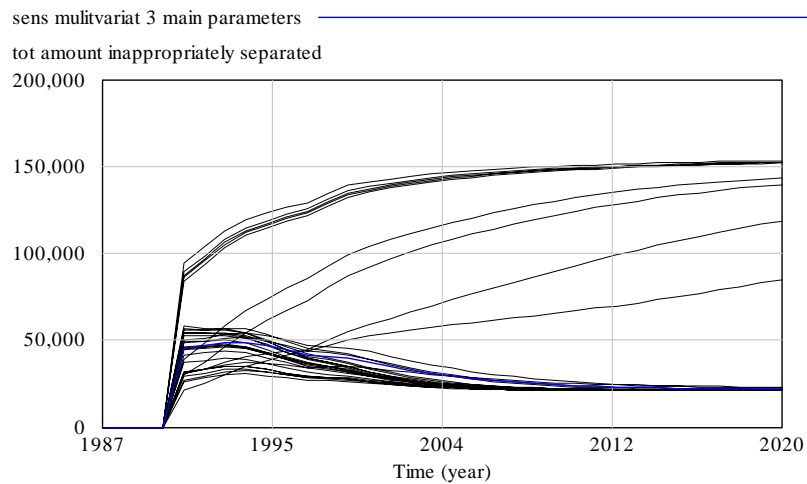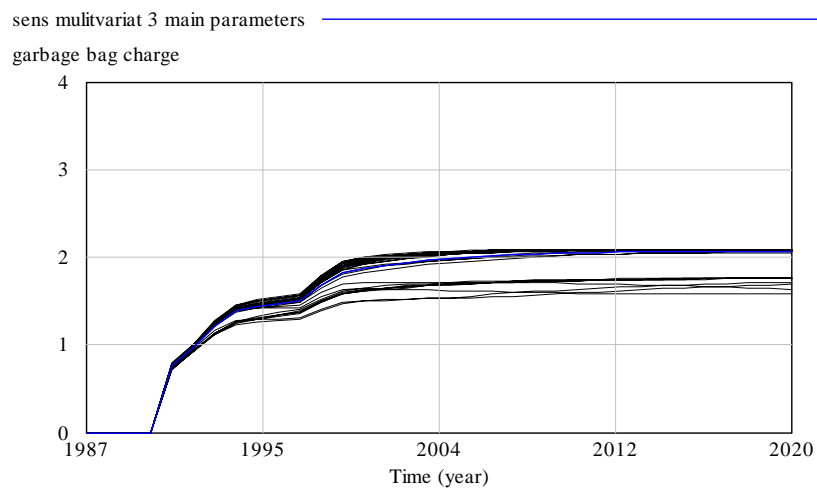
(D) inertia policy 2 – *<garbage bag charge>*

Charts 5.32 A-D : Multivariate sensitivity analysis with inertia policy 2.

5.6.6   Conclusions on model testing

Some main features of the model were discussed that should help gain confidence in the model-structure and behavior. Testing the model was an integral part of the modeling process, including structure assessment and behavior reproduction tests. The units of each variable and equation were specified during the modeling process and helped build a model structure that is both dimensionally consistent and based on variables that have real world meaning (they are operationalized). In addition the model structure is based on theoretically and empirically well-founded assumptions that generate a plausible behavior and show a good fit to the data. The model passed three extreme conditions tests showing that it exhibits a robust behavior even under extreme parameter and policy variations. The behavior mode sensitivity of three influential and uncertain parameters was analyzed in univariate and multivariate modes.

These tests showed that the model tends to exhibit behavior mode sensitivity due to the tipping point. This observation implies that uncertainty in parameters could result in different model output and inconsistent policy implications. However, the range of uncertainty in the parameter can be confined to those values that would produce the reference mode behavior. Due to strong bounds of attractions the remaining uncertainty in the parameters exhibits no further model behavior sensitivity leading to robust policy implications.

Furthermore, the tipping point in the model is an important insight that has to be taken into account for policy recommendations. It determines the failure or success of a recycling initiative and knowledge about the critical system parameters is decisive.

So far the main features of the model give evidence that the model is suitable to enhance the understanding of recycling dynamics at the local level and that the policy implications drawn from this model are robust.

5.6.7   Policy-experiments under different scenarios

In the previous section different policy-packages were tested in policy-experiments. It is assumed that actors of the system in focus can decide about those policy-levers. In the following, four policy-experiments will be tested under different scenarios. Different scenarios are determined through changes in the surroundings that are not initiated by local authorities. Contrarily the conditions in the surroundings will determine certain conditions of the solid waste management system and action possibilities of the local authorities, as well as the effectiveness of local policies. In the model, changes in exogenous parameters will define different scenarios.

The previous policy-experiments have been conducted under a **base scenario** that is characterized by a **constant solid waste generation** per year and **by well-defined unit cost for recycling and incineration**.

Parameter value base scenario			
C	Unit cost for collecting burnable material	CHF/kg	0.1
C	Incineration cost per unit	CHF/kg	0.23
C	Unit cost for collecting separated material	CHF/kg	0.2
C	Recycling cost per unit	CHF/kg	0.1
C	Solid waste generation normal	Kg/(year*person)	339

Table 5.15: Parameter values base scenario

In the base scenario the *<incineration cost per unit>* and the *<recycling cost per unit>* represent an average price condition in the recycling and incineration market, in which the localities have to pay for both services (there exist positive prices) but those for recycling are lower (*<incineration cost per unit>*: 0.23 CHF/kg and *<recycling cost per unit>*: 0.1 CHF/kg, see Table 5.15).

The following Figure 5.21 portrays the scenario leverage points in the simplified model structure, illustrating the effects on the basic loops.

Figure 5.21: Scenario leverage points influencing main loops.

The scenario leverage point **solid waste generation** reflects both the trend in the overall waste generation and in the *<total amount recyclable material>* (determined by a growing *<effective nr recycling streams>*). The scenario leverage point **changes in market conditions** reflects the effect of market prices in the incineration and recycling industries on the outcome of a local recycling initiative.

In the scenario-experiments there are on the one hand one-dimensional changes in scenario parameters and on the other hand two-dimensional changes in the scenario parameters, determining either best-case or worst-case conditions. In the model they can be specified in ranges determining for example best-case conditions in the recycling market with lower prices than in the base run or worst-case conditions with higher prices in the recycling market. Those different scenarios can be best simulated in the sensitivity analysis mode.

The two one-dimensional changes in the policy-experiments are:

Firstly, simulating an economic growth scenario with increasing *<income per capita>* resulting in a growing *<solid waste generation per capita>*. Figure 5.22 shows the model structure computing the *<solid waste generation per capita>* (adopted from (Mashayekhi 1988)).
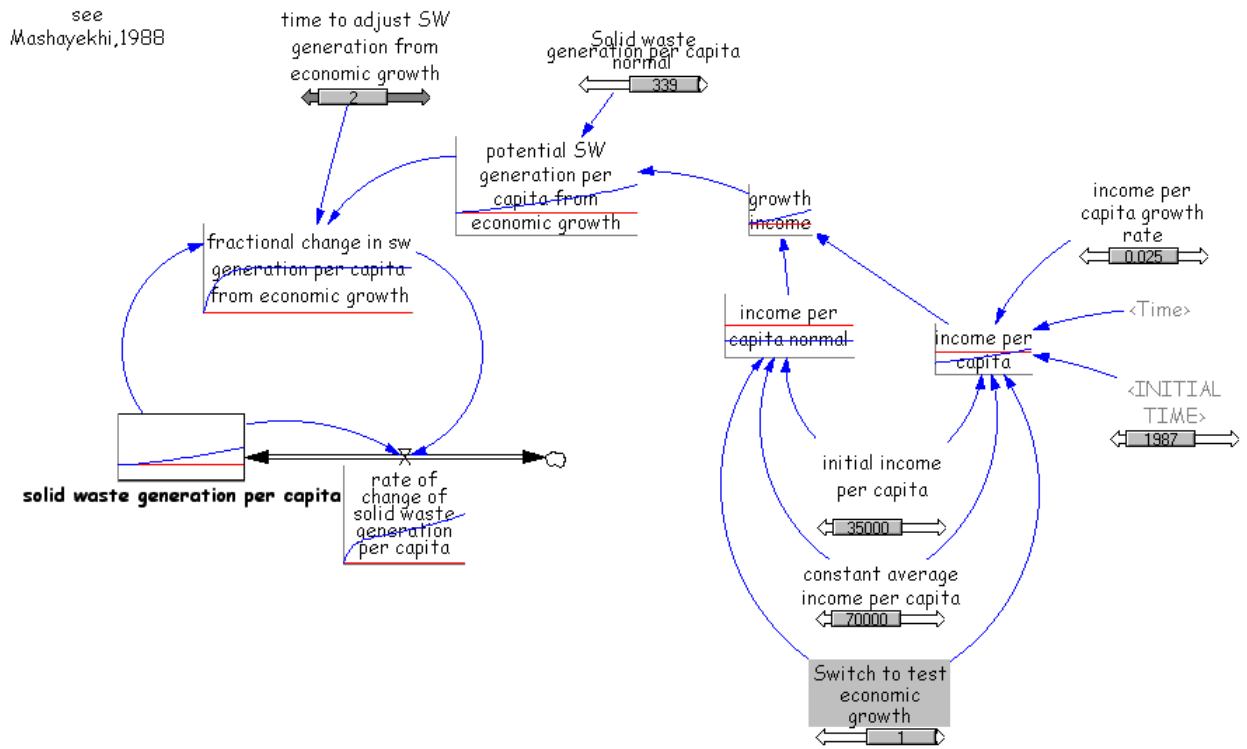
Figure 5.22: Model structure computing exponential growth in income and solid waste generation.

Secondly, simulating a further increase in <*effective nr recycling streams*> induced by the recycling market. This scenario is based on the same assumptions as described in the forecasting policy-experiments (see Figure 5.21). A take off in the recycling market would promote a market entry for new recycling technologies.

The main effects of these two one-dimensional changes are demonstrated in Chart 5.33 a under the **inertia policy 2**. Both the *<total amount appropriately separated>* and the *<total amount recyclable>* seem to exhibit a linear increase. Furthermore, the typical "first-worse-before better" behavior pattern in the *<total amount inappropriately separated>* can be observed. However, the impurity tends to grow further seeking equilibrium at a higher level towards the end of the time horizon.

On the one hand (B) shows the overall system performance measured in *<fraction separated>* with nearly no difference compared to the **inertia policy 2** under the base scenario.

On the other hand we observe in (C) a steeper increase in the *<garbage bag charge>*. The increasing amount of separated material - caused by both the increase in *<effective nr recycling streams>* and the growth in *<solid waste generation per capita>* - lead to higher *<cost that should be covered by bag charge>*.

The distinction of external conditions in best-case and worst-case scenarios for the recycling initiative constitutes the two dimensions of further changes in the model assumptions. There are four scenario parameters that can be specified as follows:

- *<incineration cost per unit>*
- *<recycling cost per unit>*
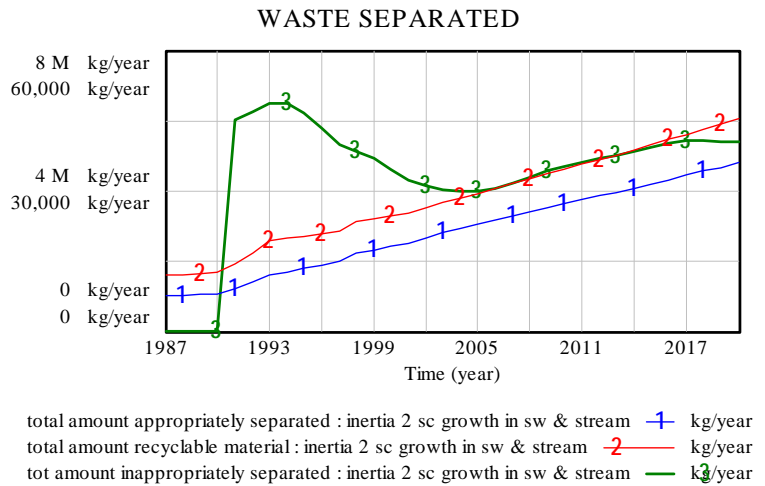
(A)
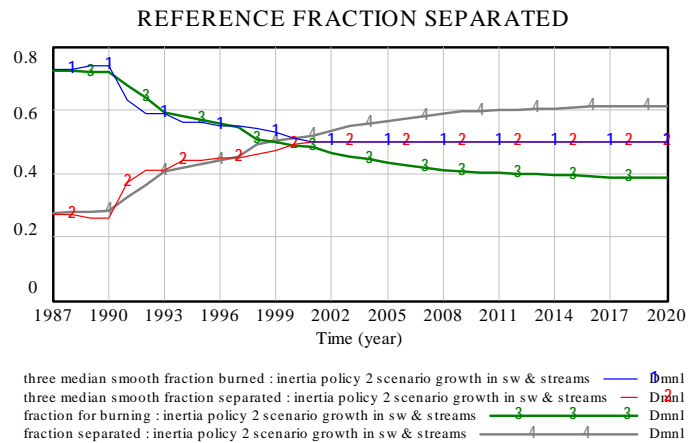
(B)
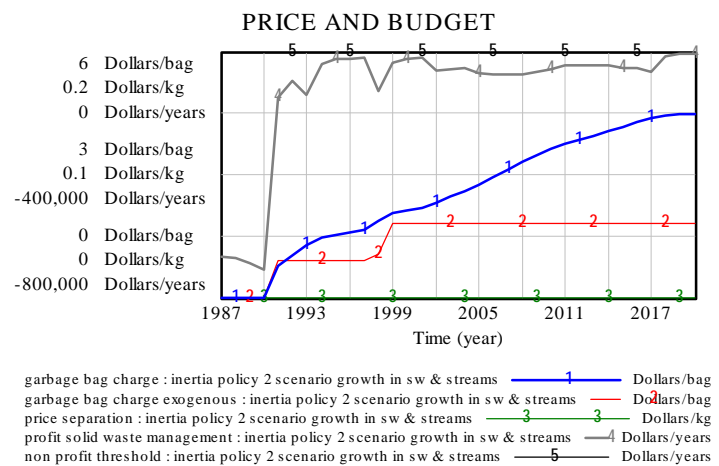
(C)

Charts 5.33: Dynamics in one dimensional scenario-experiments with inertia policy 2

- *<prepaid disposal tax>* (other actors than the local authorities will determine their value)

- *<normal unit cost of one unit of capacity building>* in the collecting points.

For each of these parameters, ranges are specified that lead either to a best- or worst-case scenario (see Table 5.16).

In addition to these two scenario-determined biases, the uncertainty range of policy parameters can bias the conditions for the policy-experiments further. For the best- (worst-) case scenario the parameter ranges are set to the most (least) favorable condition for a recycling initiative. Table 5.16 lists the parameters and ranges for the best-and worst-case scenarios for a recycling initiative. The current model value is the threshold value for the two cases.

	Scenario / Policy-lever	Units	Model value	Best-case scenario (uncertainty range)		Worst-case scenario (uncertainty range)	
				Minimum value	Maximum value	Minimum value	Maximum value
SP	Incineration cost per unit	CHF/kg	0.23	0.23	0.5	0.1	0.23
SP	Recycling cost per unit	CHF/kg	0.1	0	0.1	0.1	0.5
SP	Prepaid disposal tax 2004	CHF/kg	0.2	0.2	0.5	0.05	0.2
SP	Normal unit cost of one unit of capacity building	CHF/kg	0.14	0.05	0.14	0.14	0.5
PP	Max acceptable separation cost	CHF/(year*person)	150	150	300	50	150
PP	Max acceptable separating time	Hours/week	2	2	3	0.8	2
PP	Max acceptable cost for burning	CHF/(year*person)	180	100	180	180	300
PP	Unit cost for collecting burnable material	CHF/kg	0.1	0.1	0.5	0.05	0.1
PP	Unit cost for collecting separated material	CHF/kg	0.2	0.1	0.2	0.2	0.5
PP	Normal time per stream	Hours/(week*streams)	0.2	0.1	0.2	0.2	0.3

Table 5.16: Uncertainty ranges for best- and worst-case scenario-experiments (SP = Scenario Parameters; PP = Policy Parameters).

The purpose of this experimental design is to contrast the outcome of different policy-packages under both extreme cases considering the uncertainty in the exogenous trends and endogenous policy parameters. The experiments are conducted in the sensitivity analysis mode using the multivariate sensitivity test option. Four system indicators measure the outcomes of the experiments:

- the *<fraction separated>*

- the *<garbage bag charge>*, respectively the *<profit solid waste management>*

- The *<accumulated fraction impure material in separated waste>* as an artificial indicator for the policy effectiveness over the time horizon

- The *<accumulated total cost for waste management>* as an artificial indicator for the policy efficiency over the time horizon

Table 5.17 illustrates the design of the eight different scenario-policy-experiments aimed at analyzing the outcome of four policy-packages under either best- or worst-case conditions.

Names of policy-experiments			**Best-case scenarios**	**Worst-case scenarios**
Forecasting under different scenarios	Growth waste generation	Further increase in recycling streams after 2004	Uncertainty range biased towards most favorable conditions	Uncertainty range biased towards least favorable conditions
Low price market recycling condition				
Inertia policy 2 best-case scenarios	1	1	1	0
Implement prepaid tax with flexible bag charge best-case scenarios	1	1	1	0
Implement prepaid tax with constant bag charge best-case scenarios	1	1	1	0
Implement price for burning and separated material best-case scenarios	1	1	1	0
High price recycling market condition				
Inertia policy 2 worst-case scenario	1	1	0	1
Implement prepaid tax with flexible bag charge worst-case scenario	1	1	0	1
Implement prepaid tax with constant bag charge worst-case scenario	1	1	0	1
Implement price for burning and separated material worst-case scenario	1	1	0	1

Table 5.17: The design of the two-dimensional scenario-experiments.

Appendix A5 documents all the different simulation results in the form of confidence bounds. In the following paragraphs, a summary of the results will be presented.

Fraction separated under the different scenario-experiments

The confidence bounds in the best-case scenario are, in general, smaller than those in the worst-case scenario caused by the main characteristic of the model structure, the tipping point and the two borders of attraction (see Charts 5.34). There exists an upper and a lower limit of *<fraction separated>*. Under the best-case-conditions nearly all simulation runs reach equilibrium at the upper limit of *<fraction separated>*, around 62%. The loop **"getting motivated"** is dominant. However, under the worst-case conditions, in most simulation runs, the loop **"getting disappointed"** gets stronger; there is a clear bias in the results

towards the lower limit of *<fraction separated>* around 28%. Charts 5.34 illustrate a typical simulation result with respect to the difference in the confidence bounds for the first three policy-packages.

However, this simulation result is particularly interesting since it also shows one specific characteristic of the policy-package **implement prepaid tax with flexible garbage bag charge**. Under the worst-case conditions the different behavior of the confidence bounds reflects the behavior pattern observed in the forecasting policy-experiment depicted in Chart 5.22 in Section 5.6.3 (Forecasting policy-experiments). It exhibits the characteristics of a "first-better-before-worse" behavior pattern.

The highest uncertainty in the policy outcome even under the best-case conditions can be observed in the policy-package **implement price for burning and separated material** (see Chart 5.33). The simulation runs show a clear "first-better-before-worse" behavior pattern caused by the change in the policy regime towards showing market prices for separated material in 2004 (see Appendix A5). Fur-

A best-case-condition

B worst-case-condition

Chart 5.34: Confidence bounds in the best- und worst-case experiments: Implement prepaid tax with flexible garbage bag charge; <fraction separated>.

thermore, the experiment-result indicates that this policy-package will lead to a failure of the recycling initiative in most cases. It exhibits the smallest confidence bounds under the worst-case conditions.

Chart 5.35 depicts the confidence bounds in the simulated *<fraction separated>* at the end of the time horizon. Under a prepaid tax policy regime, a smaller confidence bound around the lower border of attraction can be observed in comparison with the **inertia policy** case.

Fraction separated (%)

Chart 5.35: Confidence bounds in the best- and worst-case experiment; *<fraction separated>*.

The wider confidence bounds in the worst-case conditions can be interpreted in the following way. For example, in the **inertia policy** the *<garbage bag charge>* could get high enough to countervail the *<effect of time cost for separating>*. Although the **"getting motivated"** loop will be weakened, the *<garbage bag charge>* would increase enough, weakening the **"getting disappointed"** loop even more. Therefore, the *<fraction separated>* could be high even under worst-case conditions. But probably in such a situation, the *<garbage bag charge>* would be so high that it would not be accepted any more. However, in the prepaid tax regime, under the worst-case conditions, an upper limit may exist that is sub-optimal to the actual possible outcome. Nevertheless, policies changing some conditions may improve the outcome; it means that the system is sensitive.

Garbage bag charge under the different scenario-experiments

The simulation results presented below show the confidence bounds of a *<garbage bag charge>* that would ensure a zero *<profit solid waste management>*-budget, with the exception of the policy-experiment-results pertaining to **implement prepaid tax with constant garbage bag charge.** For this policy-package the development of the budget will be observed. But first, we will focus on the development of the *<garbage bag charge>* in the other policy-experiments.

Chart 5.36 summarizes the test-results. Under the best-case conditions, the **inertia policy 2** experiments show a clear increase in the *<garbage bag charge>*. However, under worst-case conditions, with a slight decrease in *<garbage bag charge>*. the **"getting disappointed"** loop dominates, and with a strong increase, the **"getting motivated"** loop dominates.

Under the best-case conditions for **prepaid tax with flexible garbage bag charge** only a slight increase in *<garbage bag charge>* can be observed. Under the worst-case conditions a sharp decrease towards a price of zero is likely.

The policy-package **implement price for burning and separated material** shows that under both conditions a sharp decrease in the price is likely, concluding in equilibrium on a lower level than in the base scenario of **inertia policy 2**.
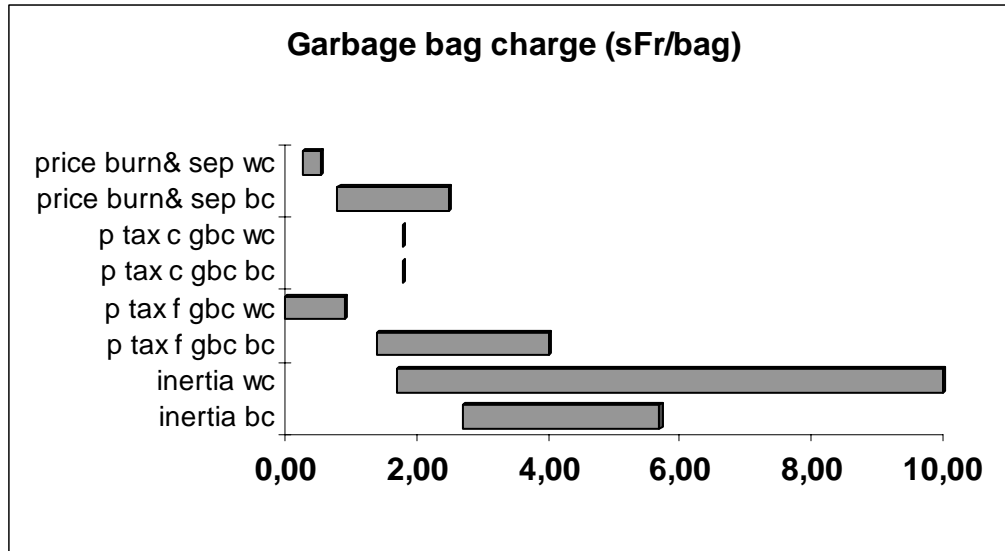
Chart 5.36: Confidence bounds in the best- and worst-case experiment; *<garbage bag charge>*.

Chart 5.36 illustrates the confidence bounds of a *<garbage bag charge>* leading to a zero deficit budget (exception in the prepaid tax policy with constant *<garbage bag charge>*). The larger confidence bounds indicate that an 'optimal' *<garbage bag charge>* is sensitive to different uncertainties. However, the chart also illustrates that under a prepaid tax regime the *<garbage bag charge>* would be in a reasonable range whereas in the inertia policy, an unacceptable charge would be indicated.

Chart 5.37 illustrates the confidence bounds under the policy-package **implement prepaid tax with flexible garbage bag charge**. The (red) line "inertia policy" depicts the *<garbage bag charge>* under the base scenario. Under the best-case conditions the *<garbage bag charge>* tends to be higher whereas in the worst-case it will be lower. Probably, in this case we can conclude that the incentives may be too low, resulting in a lower *<fraction separated>*. This development indicates a critical characteristic of the prepaid tax policy and a zero budget deficit-goal. In a worst-case scenario with low incineration cost and high recycling cost, an unfavorable price ratio could lead to failure of the recycling initiative.

In this situation a higher *<garbage bag charge>* resulting in a profit would give stronger incentives.
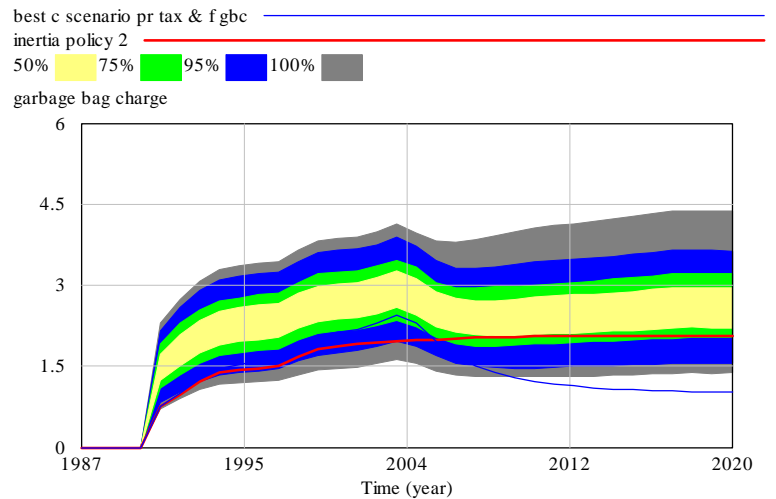
A best-case scenario
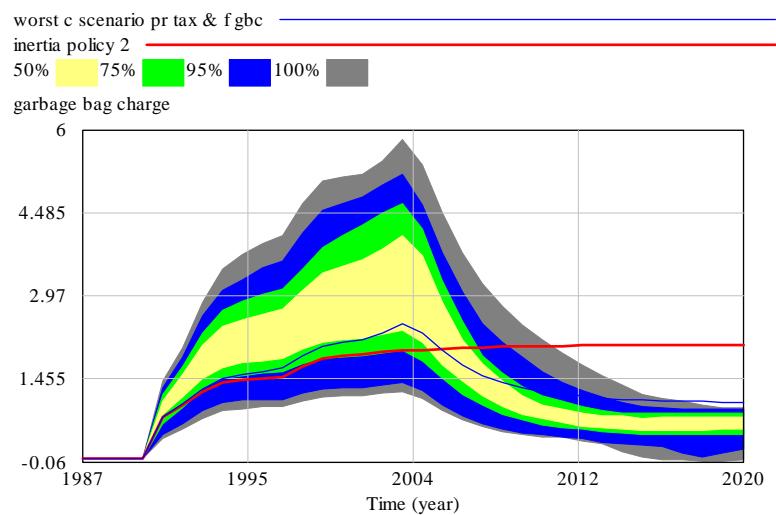
B worst-case scenario

Chart 5.37: Confidence bounds in the best- and worst-case experiments: implement prepaid tax with flexible garbage bag charge; <garbage bag charge>

The policy-experiment **implement prepaid tax with constant garbage bag charge** gives some insights about the critical path of *<profit solid waste management>* with constant a *<garbage bag charge>*. Chart 5.38 portrays the development of *<profit solid waste management>* with a constant *<garbage bag charge>*. Under the best-case scenario a constant *<garbage bag charge>* would lead to a deficit in most cases. This result is in line with the observation made in the previous experiment (see Chart 5.38 A), indicating the need for a higher charge in order to meet the zero profit goal. However, in the worst-case scenario there would be a profit. This situation could create a paradox for local authorities. On the one hand the best-case condition tends to create a deficit however, on the other hand, the worst-case tends to result in a profit.

best-case scenario

B worst-case scenario
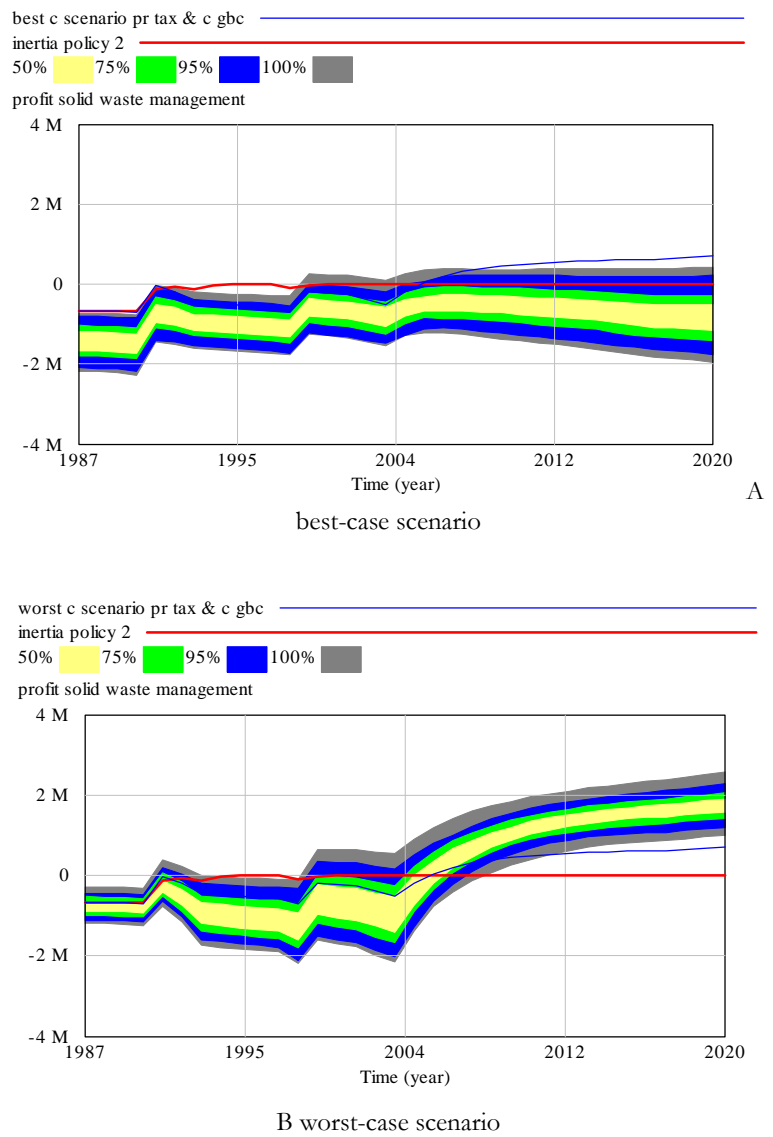
Chart 5.38: Confidence bounds in the best- and worst-case experiment: implement prepaid tax with constant garbage bag charge; <profit solid waste management>

Accumulated fraction of impure material in separated waste in different scenario-experiments

The performance indicator *<accumulated fraction impure material in separated waste>* computes the overall unintended effect of impurity and is useful for comparing the policy effectiveness of the different experiments. This indicator is a stock with only one inflow; therefore, its value can only grow or reach equilibrium.

Chart 5.39 illustrates that in the best-case scenarios all policy-packages exhibits low impurity with a narrow confidence bound. However, in the worst-case conditions there are remarkable differences in the confidence bound range. The policy-package **implement price for burning and separating** has a smaller confidence bound at the lowest level. Contrarily, the **inertia policy** under the worst-case conditions exhibits the widest range including the highest impurity level. Since the impurity is very sensitive to price incentives on burning, the uncertainty in the outcome of the *<accumulated fraction impure material in separated waste>* can be explained by the uncertainty in the *<garbage bag charge>*. In the worst-case conditions the **prepaid tax** policy-experiments show slightly smaller confidence bounds.
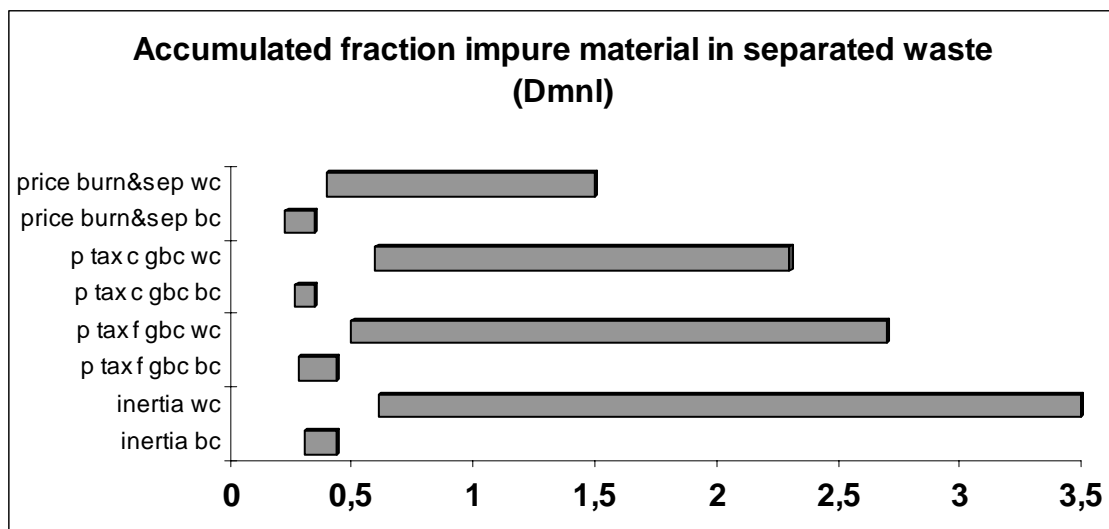
Chart 5.39: Confidence bounds in the best- and worst-case experiments; *<accumulated fraction impure material in separated waste>*.

The test results can be summarized as follows: Under best-case-conditions the different policy-packages are equally effective. However, under worst-case conditions there are wider ranges in the confidence bounds, indicating that small changes in the parameters can have a significant effect on the impurity. The policy-packages **implement price for burning and separated material** tend to be more effective with regard to impurity.

Accumulated fraction of total cost for waste management in different scenario-experiments

The indicator *<accumulated fraction total cost for waste management>* has the same characteristics as the *<accumulated fraction impure material in separated waste>*. It can only show an increasing behavior mode.

Chart 5.40 illustrates that as a result of outsourcing the task of collecting separated material to the retailers, the policy-packages under the **prepaid tax** regime tend to reduce the cost for municipal solid waste management. Under the **inertia policy** the costs are highly sensitive to the uncertainty in the parameters. High prices in the recycling market would strongly increase the overall management cost. In this situation the localities would perceive recycling as economically unreasonable.

**Accumulated total cost for waste management
(Million - Dollars)**

price burn&sep	
price burn&sep bc	
p tax c gbc wc	
p tax c gbc bc	
p tax f gbc wc	
p tax f gbc bc	
inertia wc	
inertia bc	

0   50   100   150   200   250
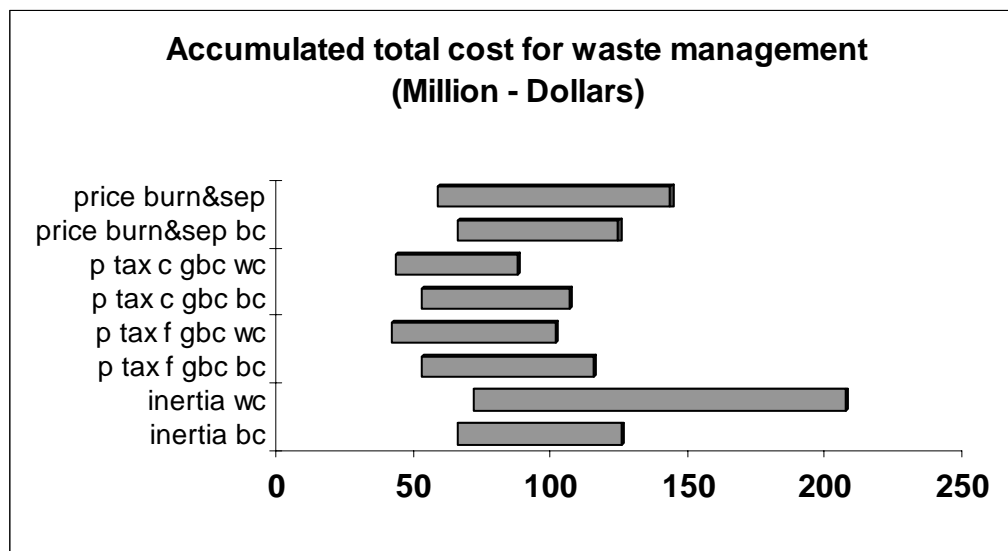
Chart 5.40: Confidence bounds in the best- and worst-case experiments *<accumulated total cost for waste management>*.

5.6.8   Insights from the policy-experiments under different scenarios

The results of policy-experiments under different scenarios highlight some important differences compared with the base scenario back-casting and forecasting policy-experiments. The growth in *<solid waste generation per capita>* and the further increase in *<effective nr recycling streams>* seem to enforce the dynamics that lead to the two main side effects. Firstly, the impurity starts to grow again after the "first-worse-before-better" pattern observed in the first half of the time horizon. Secondly, the *<garbage bag charge>* steadily increases due to the higher *<total amount separated>*. Both effects boost the *<costs that should be covered by bag charge>* further.

One important insight is that the *<garbage bag charge>* seeks equilibrium only towards the end of the time horizon. This observation implies that authorities would need to adjust the *<garbage bag charge>* several times in the observed time horizon. This may raise new questions related to social and political acceptance.

However, under **inertia policy 2** the *<fraction separated>* would seek equilibrium at a slightly higher level (61% compared to 54% in the base scenario). This result is surprising because we could expect that people could get overwhelmed from the separation task induced by the *<increasing nr recycling streams>*. The **"getting motivated"** loop will indeed be weakened by this effect. Conversely, the increasing *<garbage bag charge>* will weaken the **"getting disappointed"** loop. As long as the former dominates the latter, the recycling initiative will succeed.

The various scenario- loop experiments give an idea of the competing forces acting on these two loops and highlight the ranges of possible policy-outcomes.

If the system were biased towards a favorable situation, both a garbage bag regime and a prepaid tax regime would lead to an optimal outcome with high certainty. Given such a situation, the difference between the **inertia policy** and a prepaid tax regime with respect to the *<fraction separated>* and the *<accumulated fraction impure material in separated waste>* is small. Both regimes will be almost equally efficient. The main goal of the prepaid tax regime could be reached, i.e., to disburden the municipalities from the high cost. However, uncertainty in the system could raise some issues that have to be considered, especially when we have to expect disadvantageous conditions. Worse conditions strengthen those loops that drive the dynamics towards the lower border of attraction, resulting in a failure of the recycling initiative. In all experiments involving worst-case conditions, we can observe that the *<fraction separated>* converges toward the lower limit. But the large confidence bounds give evidence that little changes in the uncertain parameters may have a significant effect on the outcome.

At this point some main characteristics of the prepaid tax experiments will be addressed. In the worst-case scenario only a sub optimal outcome could be reached. There are no endogenous dynamics that try to compensate for bad conditions such as low prices for burning or a low willingness to spend time on separating. Contrarily, the prepaid tax decreases the *<cost that should be covered by bag charge>*, resulting in a lower charge and enforcing the loop **"getting disappointed".** A low *<max acceptable separating time>* weakens the loop **"getting motivated".** Therefore, the pool willing people will be depleted even faster.

The dynamics in the budget of solid waste management highlights an additional critical point relating to the prepaid tax regime. The countervailing price effect of a flexible *<garbage bag charge>* was already addressed earlier. The zero budget deficit goal would enforce the effect of an unfavorable price ratio determined by the market conditions in the recycling and incineration industry. Lower burning prices result in lower *<garbage bag charge>*. As a consequence, the loop **"getting disappointed"** will be enforced. Furthermore, this would also decrease the overall solid waste management budget, indicating that this policy strategy is economically efficient. **There would be a trade off between an economically efficient strategy and an effective strategy**. Since the local authorities do not feel anymore responsible for an effective outcome of this recycling initiative - this task will be delegated to the retailer to some degree - they are not urged to improve the situation.

This trade off is emphasized even more in the case with a very low constant *<garbage bag charge>*. In the worst-case scenario, the policy **implement prepaid tax with low constant garbage bag charge** would lead to a profit in solid waste management and to a decrease in the *<fraction separated>*. In the case of an increase in the number of recycling streams, citizens get overwhelmed, which will shut down the fraction getting motivated. In this case, the *<garbage bag charge>* cannot counteract the depletion of the pool **<ep willing to separate>**.

The two cause strips (Chart 5.41) demonstrate the strength of the effects acting on the two loops **"getting motivated"** and **"getting disappointed".**

These dynamics would lead to a failure of the recycling initiative, resulting in a higher amount of material for burning and a higher income. This would lead to a *<profit solid waste management>* due to the constant *<garbage bag charge>*. Here again the localities would not have an incentive to change their strategies and to improve the situation. Furthermore, in order to correct this situation, higher *<garbage bag charge>* should be implemented earlier on. But this solution would be counterintuitive. Why would the localities increase the *<garbage bag charge>* if they were already making a profit in solid waste management? These observations demonstrate that under bad conditions it becomes harder to correct the system, since the dynamics show a strong path dependence that could lock in the current situation due to a wrong monitoring and control system. **In this case, probable policy resistance is a result of two distinct reasons: extremely low incentives for separating and a misleading controlling system in solid waste management.**

The policy implication of these critical observations will be discussed further in Chapter 6.1 (Policy implication).

Focusing on the policy-experiment **implement price for burning and separated material** contrasts the results of the other experiments. This policy-package is less robust in the best-case scenario than the other tested policy-packages and it will fail for sure under the worst-case conditions. This result suggests that this policy-package could only bring a better outcome in separation behavior resulting in less impurity under best-case conditions.

In a worst-case scenario people will have a lower *<max acceptable time for separating>*. In addition the increase in "*<effective nr recycling streams>*" increases the required *<time spent for separating>*, therefore, the *<effect of time cost separating>* would shut down the fraction getting motivated early on. There is no further inflow in the pool *<ep willing to separate>*. The *<effect of burning cost>* reduces the out-flow of the pool slowing down the depletion of the pool *<ep willing to separate>*. However, high separation cost would lead to an *<effect of crowding>* resulting in a small peak in the *<fraction becoming willing>* in the middle of the time horizon.
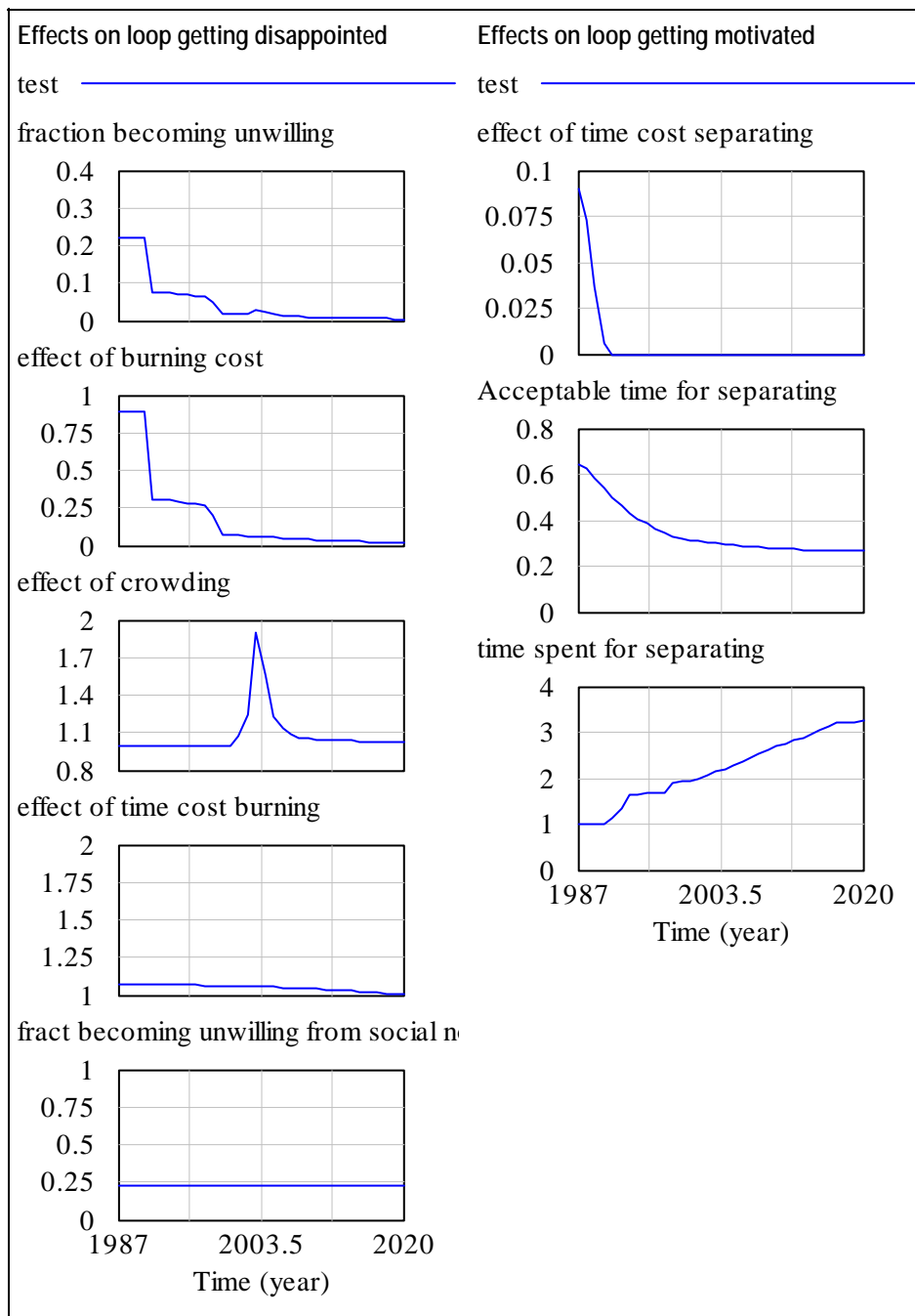
Chart 5.39: Causal strip graphs illustrating the effects of a prepaid tax with constant *<garbage bag charge>* under a worst-case scenario.

6 Discussion and reflection on policy, theory and method

This chapter is organized in two parts. In the first part, crucial policy-implications are discussed that were derived from the computer assisted policy analysis reported in the previous chapter. In the second part we will reflect on the study.

Thus far, many insights on the issue of environmentally relevant behavior and public policy have been gained, specifically for solid waste management at the local level. They help address the research questions and will be reported in this chapter.

1. *Which factors influence human behavior that lead to harmful environmental consequences in the area of solid waste management?*

2. *Which are the causal structures that produce unintended consequences? What are the interactions between personal attributes (e.g. preferences) and contextual variables (e.g. prices, opportunities to act)?*

3. *Which interventions are suitable to reverse harmful trends in solid waste management?*

4. *Which strategies are most effective? Which combination of policy instruments is most promising?*

Practical recommendations pertaining to these questions are discussed in Section 6.1 (Policy implications) whereas Section 6.2.1 (From a key factor perspective towards a key loop perspective on environmental policy) addresses the questions from a theoretical point of view.

In the second part, the study will be reflected upon: What has been done? What are the strengths and the limitation of this study? By now the objectives of the study are reached, specifically *a computer based learning environment has been created that both highlights the interplay of economic, ecological and social, and personal factors in solid waste management. It helped to analyze the impact of different policies and solid waste management strategies.*

6.1 Policy implications

This section addresses the specific observed real world concerns in local solid waste management that were guiding the model conceptualization. The policy concerns have been captured in the following question.

What local policies increase recycling, reduce the overall generation of solid waste, and help establish / ensure a solid waste management that fosters competitive recycling markets?

In order to simplify this overarching challenge the suggestions focus on the three sub-questions as introduced in Section 5.2.1:

1. *How do you motivate the households to participate in solid waste separation?*

2. *How do you recover recyclable material to produce competitive secondary raw material?*

3. *How do you finance the recovering and disposal activities of local agents?*

For each, specific policy implications will be discussed in a separate section. This section begins with an explanation of the observed phenomena and concludes with some subsequent remarks on policy implications stressing the role of monitoring the right parameters and the importance of a profound system understanding.

6.1.1   What caused the problems?

The causal structure of the model and the dynamics explain what caused the observed problems referring to the **recurring deficit**, the **observed impurity** in recycling streams and the **growing costs** of solid waste management. Furthermore, it gives a plausible explanation of the observed development of the *<fraction separated>* and about limiting factors of growth and decay. From these insights we can derive some general policy implications.

To begin with, the **recurrent deficit** will be addressed. The main assumption of economic theory underlying a garbage bag policy is that equilibrium exists that would lead to a social optimum and would be in line with a "polluter pays principle". However, the model shows that reality differs from this theory in two distinct ways. On the one hand, internal dynamics (caused by price incentives and implicit cross-subsidies, explained in the dynamic hypothesis in Section 5.3.1) would require raising the bag charge continuously. This effect is well explained in the economic literature (e.g. see Weimann 1991:148, or Atkinson and Lewis 1974). On the other hand, changing external conditions such as changes in unit costs or the fraction of recyclable material give evidence that an equilibrium price has to be adjusted to those changes. Delays and limitations in the price adjustment process will result in a deficit. We can conclude that the observed deficit is a logical consequence of the structure of the system and not one of mismanagement of solid waste at the local level.

This is one important insight. But an even more significant implication of the policy experiments relates to the management of dynamically complex systems. The insights from the forecasting-experiments (Section 5.6.4) and the policy experiments under different scenarios (Section 5.6.8) indicate that having the right management model may be essential to interpret the overall solid waste management-performance. This issue will be addressed more explicitly in the Section 6.3.

Secondly, the observed **dynamics in impurity** is a consequence of an initial policy resistance and adjustments delay in personal factors such as *<acceptable time for separating>* and *<acceptable unit cost for burning>*. However, it would alleviate overtime (ceteris paribus). The observed dynamics come from the diffusion process explaining the number of people willing to separate. It results in a "first-worse-before-better" dynamic pattern. However, according to the test results the impurity problem would be mainly solved if the whole population would be willing to separate.

In order to avoid the harmful side effect of policy resistance, policy interventions aiming to build up altruistic norms and intrinsic motivations to separate are suggested. For these interventions, policy instruments such as communication instruments and collaborative agreements influencing personal factors might be effective. They would increase the

willingness to invest time in separation behavior. Some empirical experiments presented in the literature demonstrate the range of their effectiveness (i.e. Hopper and Carl-Niesen 1991, Guagnano, Stern et al. 1995).

Thirdly, the **growing cost** is mainly a consequence of a successful recycling initiative but also of impurity and growth in solid waste generation. Policies reducing the impurity problem would slow down the cost growth. The dynamic hypothesis **"trap / chance recycling market"** (see Figure 5.7 in Chapter 5.3.1) suggests that offering different recycling streams and motivating people to separate waste is a cost effective approach over the long run. Therefore, the local investments in the separation capacities of citizens could be worthwhile.

Finally, the model illustrates that the *<fraction separated>* depends on the number of *<ep willing to separate>* and on the *<effective nr recycling streams>* determining the overall fraction of recyclable material. If there was already a certain *<perceived social norm separating>* in a community, the effect of an increase in the *<effective nr recycling streams>* would increase the amount of separated material. Conversely, in a community with a low *<perceived social norm separating>*, an increase in the *<effective nr recycling streams>* can overwhelm the people, resulting in even less appropriately separated material. The effect of an increase in the *<effective nr recycling streams>* depends not only on the *<perceived social norm separating>*, but also on the overall *willingness to invest time in separation*. The upper limit indicates a maximal capacity to separate. This interpretation of the observed tipping point in the model behavior suggests that in the long run a successful separation-strategy has to be sensitive to the *<effective nr recycling streams>* that are offered. The important information is the *potential capacity of the citizens to separate* but also the *potential capacity to separate in the recycling sector*. The latter will depend on the market development and the former on the *<perceived social norm separating>* and the maximal willingness to invest time in separation activities.

By now the model helped to structure and explain the observed management issues. Having a clear picture of the perceived problems is a first step. Based on this understanding and on the results of the policy-experiments crucial policy implications will be discussed. Furthermore, some recommendations will be given addressing the "real world concerns".

6.1.2 How do you motivate households to participate in solid waste reduction and separation?

The question *"How do you motivate households to participate in solid waste reduction and separation?"* can only be partially addressed with the help of this model. To begin with, the limitation of the current model is emphasized. The model does not include any feedback controlling the waste generation endogenously. Therefore, no policy implication with respect to waste reduction behavior can be made. However, the model structure could be expanded in order to address this question.

Conversely, some robust policy implications can be drawn from the model, which are related to the question *"How do you motivate the households to participate in waste separation?"*

The various policy-experiments give evidence that under best-case conditions all the discussed policy-packages would be successful in motivating people to separate. However, a good public policy should also be robust under worst-case conditions. Under worst-case conditions, the analyzed policy-packages exhibit different ranges of confidence bounds in the outcome of separation behavior. These indicate both more or less robust policy-outcomes and policy sensitivity to changes in the parameters. The sensitivity analysis demonstrates that the two parameters *<max acceptable separating time>* and *<normal time per stream>* are critical policy parameters influencing the loop **"getting motivated"** (see Chapter 5.6)**.** They seem to be important leverage points.

Yet, the analyzed policy-packages with garbage bag charges mainly intervened on the loop **"getting disappointed".** Since the *<garbage bag charge>* has a higher elasticity in the inertia policy, this policy-package seems to counteract some worst-case conditions like "***high*** <recycling cost per unit>" or a *"**lower** <max acceptable separating time>".*

However, the demonstrated countervailing effect of sensitive garbage bag charges will be limited in the real world by acceptance problems and delays in price adjustment processes. Therefore, other policies would be needed to compensate for or correct bad conditions in the system. On the one hand, public policies should be able to compensate for "bad" recycling-market-conditions (exogenously determined conditions) and on the other hand they should have the "power" to correct "bad" conditions within the system, particularly a ***low*** *<max acceptable separating time>* or a ***high*** *<normal time per stream>* (partly endogenously determined conditions). The demonstrated limitations and unintended side-effects of the economic instrument, as well as the identified leverage points give evidence that a robust policy should combine policy interventions acting on both loops **"getting motivated"** and **"getting disappointed"**. This insight is especially meaningful for a policy strategy working with prepaid taxes. The policy-experiments showed that one main weakness of this policy is the lack of power to motivate people to participate in separating. The dynamics of countervailing price effects lead to a trade off between policy efficiency and a zero profit budget goal. Whereas an effective policy tends to lead to a deficit, policy failure tends to lead to a profit. This trade-off could make a recycling initiative economically questionable and lead to wrong decisions based on a wrong navigation model.

Different case studies and field experiments based on psychological theories addressed the question how to motivate people to participate in recycling initiative in detail, (see for example Guagnano, Stern et al. 1995, Reno, Cialdini et al. 1993, Hopper and Carl-Niesen 1991, Terry, Hogg et al. 1999). They give evidence that communication- and diffusion instruments combined with service and infrastructure instruments are effective.

6.1.3 How do you recover recyclable material in order to recover competitive secondary raw material?

One important lesson learnt is that market prices from the recycling industry and the purity of the separated material are crucial variables in the system. In order to recover secondary

raw material, the present strategy in the real world "offering different recycling streams and investing in citizens' separation behavior" is seen as a cost efficient strategy.

Therefore, in the model, the recovery-strategy "offering for every recyclable material a separate recycling stream" was tested in a variety of different policy-experiments. With this local recovery-strategy the recycling industry would get relatively pure material that was already sorted out by the citizens. On the other hand, the recycling industry would charge the localities cheaper prices for processing. However, some factors exist that would limit the effectiveness of this strategy.

Limits to growth in *<fraction separated>*

In this paragraph the observed upper limit of the *<fraction separated> will be addressed*. The experiment results illustrate that there exists an aggregated *maximal propensity to separate* - measured with the *<fraction separated>* - that depends on different factors and the state of the system:

- The maximal number of people that could become willing to separate: In the model it is assumed that there exists a small fraction in the population that would show policy resistance under each situation.

- The separation habits of willing people: How much can willing people effectively separate?

- The inherent fraction recyclable material in waste: How much material could be recovered theoretically, given the existing recycling technologies and the composition of "waste"? In the model, the *<effective nr recycling streams>* determines this fraction.

Knowing that the observed propensity to separate is a highly aggregated indicator including different factors is important for public-policy-making.

Firstly, any changes in the mentioned factors will also change the maximal propensity to separate. Secondly, a lower observed propensity could be caused by any of those factors. Thirdly, having a better understanding of factors determining the propensity to separate helps to assess the *compliance gap*. The difference between the *<total amount recyclable material>* and *<total amount appropriately separated>* is called compliance gap. The experiments showed that there would always be a compliance gap due to the maximal propensity to separate (see Chapter 5.6.1 and 5.6.2).

Distinguishing these two measures helps assess the effectiveness of a local policy initiative. The reference value would be the maximal propensity since the *<actual recyclable material per person>* would be a theoretical value that does not take into account the limits of people to separate. We can conclude, firstly, that policies aiming to improve the propensity to separate would minimize the compliance gap but, secondly, policy makers also have to be aware of how far they can push it, since the three identified factors (number of people willing to separate, separation habits, and the inertia fraction recyclable material in waste) will limit the maximal propensity to separate.

In addition, the different policy-experiments illustrate that the effectiveness of the recovery-strategy "offering for every recyclable material a separate recycling stream" will also be limited by two main factors; firstly, by the *<acceptable time for separating>* and, secondly, by decreasing marginal return of an additional recycling stream, represented in the *<multiplier for recyclable material from effective nr recycling streams>*. Once the maximal effectiveness of the recovery-strategy will be reached, another strategy has to be used in order to push the effectiveness of the recycling initiative further. One possible way could be to design additional streams in such a way that compound material could be easily recovered. Such a strategy must be aligned with the development in the recycling industry and must be convenient for the citizens.

An **advanced warning indicator** signifying that the limit will be reached would be a decrease in compliance. This measurement would compare the marginal growth in recyclable material per stream and the marginal growth in the propensity to separate. If the increase of an additional recycling stream increases the compliance gap means that some people will be overwhelmed by this additional task. Over time, overwhelmed people would enforce the **"getting disappointed"** loop.

Seeking the upper border of attraction

Until now we have discussed in detail factors that limit the propensity to separate by tracing the dynamics of the policy-experiments back to the model structure. As discussed above, the first important intervention strategy would be to apply motivational and diffusion techniques that are based on psychological and socio-psychological theories. Those techniques aim at gaining more citizens to participate in the recycling program, resulting in an improved separation outcome. However, the theory in the model suggests that separation behavior is seen as a routine behavior that is based on established habits, or everybody's automatic behavior-patterns. Therefore, the intervention strategy applicable in this case would be to improve separation habits. As the former intervention strategy aims at motivating people, the latter intervention would aim at breaking frozen disposal-behavior (Lewin 1958) and to initiate the development and establishment of more adequate habits. For example Dahlstrand and Biel (1997) emphasize the need of service and infrastructure instruments, as well as communication instruments.

These theoretical considerations and the test results of the scenario-experiments suggest that in order to design a robust recycling strategy, additional policy instruments such as "communication and diffusion instruments" and "service and infrastructure instruments" should be used. Especially for the case of a prepaid tax policy those additional policy instruments would compensate its drawback.

In the SD-SWM-model these interventions would act on the leverage points *<normal time per stream>* and *<max acceptable separating time>*. In order to test the effectiveness of the proposed policy intervention with the help of the model, an additional policy-experiment will be designed. It is reported in this chapter, because this additional policy-experiment should help test the derived implications. Furthermore it illustrates, how the model can be

used in the application context in order to assess arguments about policy robustness and to test hypotheses – thus helping master complex dynamic issues and to strengthen those arguments with explicit models (see also Schwaninger 2003a).

For the policy-experiment **complement prepaid tax with communication, service and infrastructure instruments** the same setting was mainly applied as in the worst-case scenario-experiment **implement prepaid tax with *constant* garbage bag charge** and implement **prepaid tax with *flexible* garbage bag charge**. However, for the parameters *<max acceptable separating time>* and *<normal time per stream>* the settings for the best-case scenario were chosen.

The outcome of this policy-test is depicted in Charts 6.1 A-B. In the experiment with a *constant* garbage bag charge, the test result shows a very robust policy outcome (A). The *<fraction separated>* would seek equilibrium at the maximal propensity to separate nearly for all parameter combinations. This indicates that additional policy interventions at the local level could turn the prepaid tax system into a robust strategy. In the experiment with a *flexible* garbage bag charge (B) the policy outcome is less robust. This suggests that more elaborate policy interventions are necessary causing stronger parameter changes in the desired direction. However, both test results illustrate that the suggested policy intervention creates a more robust outcome under a prepaid tax regime.

Based on these test results and theoretical reflections the following concrete measures are seen as important: offering information and opportunities to separate in different contexts such as public places and working places. Those would demonstrate separation behavior and would illustrate how citizens could organize their household in order to facilitate their separation behavior resulting in new habits. A second interesting observation derived from the model structure is that public policy tools that aim at improving separation habits would also reinforce the loop "getting motivated". This postulated hypothesis is in line with Hopper and Carl-Niesen (1991) statement: " It is possible that block leaders influenced behavior directly through a process of behavior modeling and imitation, suggesting the continued but expanded use. ... Indeed, it is also possible that behavioral change, shaped by

(A)

(B)

Chart 6.1 A-B: Testing leverage point <max acceptable separating time> and <normal time per stream>.

modeling and imitation, preceded and then facilitated changes in recycling attitudes"(217). It would offer a promising opportunity for further empirical policy research based on psychological theories.

6.1.4   How do you finance the recovering and disposal activities?

In the previous paragraphs the importance of well-designed policies for a successful recycling initiative were discussed. Now some economic consideration will be addressed. In the policy-experiments three different unit-pricing-systems were tested that should help both to cover the cost and to promote separation behavior: **a garbage bag charge policy**, **a prepaid tax for recyclable material with a garbage bag charge** and thirdly **unit prices** for both waste qualities. The economic theory tells us that those approaches would support a social optimum under well-defined steady state conditions. However, the experiments

demonstrated that in reality, internal dynamics – caused by adjustment delays, nonlinear acceptance variables or exogenous changes - raises more questions than only transaction cost and implementation issues. The System Dynamics model gives an idea about the price- and cost-dynamics in the transition phase. A successful recycling initiative with garbage bag charges tends to generate a deficit due to the discussed internal dynamics. In the inertia policy and the prepaid tax experiments, "profit" is not a reliable indicator for the success of a recycling initiative. However, the scenario-experiments show that a **prepaid tax policy with a garbage bag charge** tends to decrease the cost of the municipal solid waste management budget. A further advantage of this policy is, that the <*garbage bag charge*> would stay within an acceptable range. The main difficulty would be to determine both the "right" value of the prepaid tax and of the garbage bag charge. The simulation runs suggest keeping the garbage bag charge at the "inertia policy" level or to increase it slightly. Additional investments in communication, and service and infrastructure policies could either be covered by a surplus of the garbage bag charge revenue or a general "waste management tax", since the cost of those policies do not depend on any quantities of the different waste qualities.

Alternatively, unit pricing for separated and burning material could be considered as an efficient financing system. However, the simulation run indicates that as long as the prices for separated material would be higher than for burning, the price incentives would counteract the overarching goal to promote waste-separation behavior. In addition, setting the right price for each recycling stream and collecting the money would raise further issues, such as efficient administration and implementation. The implementation cost of such a policy could be prohibitive.

6.1.5   Concluding remarks on policy implications

The various interactions between policy effectiveness and economic efficiency turns solid waste management into a complex task for local actors. Finding the right prices that cover the costs and give the right incentives is particularly difficult due to countervailing price effects on waste-separation behavior. Not only should the budget goal be controlled but the policy outcome as well. Under a prepaid tax regime, this task would get even more challenging since more actors with different goals will be involved. Therefore, the challenge of solid waste management is not only to find the right policies but also to find the right information that guides a solid waste management system fostering competitive recycling markets. This raises the question: "Who will collect the required data and coordinate the information flow between the different stakeholders?"

The SD-SWM-model shows evidence that knowledge about the following system parameters and variables is important:

- How much time should citizens invest in order to fulfill the waste separation task?

- How much time are citizens willing to invest in separation behaviors?

- What is the maximal propensity to separate that can be reached under the given situation?

- What is the minimal compliance gap?

- How profitable is the recycling industry? Where could further investments be made in sorting capacities?

- What is the ratio of unit cost of material that is set aside for burning and recycling?

- What is the ratio of unit cost of secondary raw material and virgin resources?

Local authorities have to be aware that the task they are dealing with is not just for managing the waste but also to induce behavior change in the overall system. This is a crucial endeavor that calls for a profound understanding of the dynamics in the system and for cooperation between the different stakeholders. However, the policy-experiments show that local authorities can make a difference even in worst-case situations but only to a certain limit. Furthermore, having the right monitoring and controlling system may be crucial (see Chapter 6.3).

6.2   Framing SD model building and policy analysis with a feedback perspective on human behavior and public policy: a perfect complement

This modeling project is strongly guided by the framework *"a Feedback Perspective on Human Behavior and Public Policy"*. This perspective influences the model design in two ways.

Firstly, it helps focus on "hidden" personal factors acting as a stock in the system. The theory emphasizes the existence of such factors, and helps identify relevant concepts. It gives an idea of how they affect the system and helps incorporate them in the model. Disposal habits of a group of people could be formalized as a stock being measured by the amount of appropriately separated material. Reflecting on the observed overall propensity to separate gives evidence that it is determined by different factors such as different behavioral habits of groups of people. Subsequently, observed changes in the propensity to separate indicate either changes in behavioral habits of people, or changes in the attitude toward separating, leading to a differently structured society with new social norms. Furthermore, this line of thinking sharpens the focus on processes, explaining

- how contextual factors and personal factors interact with each other,

- how they influence the decision points,

- how and where they affect the state of the system.

Likewise, the System Dynamics modeling approach underscores this thinking discipline with its specific modeling paradigm that on the one hand requires inclusion of all the important driving forces identified, even when numerical data are missing and on the other hand requires that each parameter and variable have its real world counterpart that is specified by correct units. In addition, the requirement that all decision rules in the model

have to be based only on the available information, lead to a model of the real world that reflects crucial information deficits and perception biases. Furthermore, this requirement reflects a basic psychological statement – that is also emphasized in the feedback theory on human behavior - that deliberation processes are based on the perception of the contextual situation, hence on a subjective or ipsative action frame and not on an objective one.

Secondly, *"the Feedback Perspective on Human Behavior and Public Policy"* also guides the search for possible intervention points in the system. With the picture in mind that interventions can affect both personal and contextual factors, different intervention strategies can be envisioned. While the framework illustrates different intervention points, the System Dynamics model helps differentiate among those and also gives an understanding about the dynamics and effectiveness of interventions. Policy interventions aiming to enforce the diffusion process may differ from policy interventions that aim to improve separation habits of inexperienced but willing people.

To conclude, complementary insights can be gained by applying the framework for SD model building and policy analysis. Furthermore, the compatibility of the suggested framework with the novel typology of policy instrument suggested by Kaufmann-Hayoz, Bättig et al. (2001d) may enhance the usefulness of the decision support models in the application context.

6.3 From a key-factor-perspective on environmental policy towards a key-loop-perspective on managing for sustainability

The present study focused on relationships and interactions between important factors that influence the separation behavior of citizens. According to the established sub-goals of the main study, complex interactions and processes over time were visualized in causal loop diagrams that explain the observed phenomena in solid waste management (see Figure 5.12 in Section 5.4.3 and Figure 5.19 in Section 5.6.2). In this Section those insights will be summarized and the research questions will be discussed from a theoretical point of view.

As this research evolved, a switch in perspective took place. While the preliminary study focused on key-factors explaining environmentally relevant behavior, the System Dynamics analysis investigated key-loops. System Dynamics offers the unique possibility of identifying feedback loops as causes of system behavior. Richardson and Pugh (1981) point this out as follows :

> *"The feedback view antiquates the notion of a simple, linear, left-right causality. Chickens and eggs are not a causal dilemma if one focuses on what they cause together, namely, exponential growth in the barnyard. So, in hunting for the causes of model behavior, we seek feedback structures, not isolated variables. While a single factor can change the strength of a feedback loop and affect its dominance in the rest of the model, it is more useful to see the loop, not the factor, as the causal agent in the system"* (268).

With this focus, the research questions will be discussed from a key-loop-perspective. With the help of the SD-SWM-model **five main loops were identified as the causes of observed behavior patterns**, which are listed in Table 6.1 below. Furthermore, factors are identified that influence their strength. In addition, they are traced back to personal and contextual factors. Final, the theoretical concepts are named that explain the applied rationale forming the model structure and subsequently the loops. Finally, preliminary conclusions for solid waste management are highlighted that are important for steering towards sustainability.

The success or failure of a recycling initiative depends on the relative strength of the two loops **"getting motivated"** and **"getting disappointed".** Loop dominance is crucial. Therefore, factors that determine loop strength are crucial. However, sensitivity analysis and various policy experiments under different scenarios helped identify the high leverage points for controlling system behavior. These insights help determine why and when which preconditions for ESA should be adjusted.

The result of this key-loop-analysis can be structured according to compliance, natural environmental effectiveness and economic rationale issues:

Under the aspect of *citizens' compliance* with the recycling initiative, no further interventions may be necessary, since currently the **"getting motivated"** loop dominates the **"getting disappointed"** loop. In the given situation, the recycling initiative in the municipality under investigation is successful.

However, the *economic rationale* contradicts this observation. The recurrent deficit and the high cost of solid waste management for the municipality are dissatisfying. Hence, the economic rationale suggests further interventions. Subsequently, the dominance of the three loops **"less burning increase price"**, **"less burning reduce cost"**, and **"more separation increases cost"** together with the two compliance loops **"getting disappointed"** and **"getting motivated"** have to be controlled as described in the previous Chapter 6.1 (Policy implications).

In addition, Table 6.1 brings out a rather astonishing point related to aspects of *environmental effectiveness*. In the model no loop controlling the environmental efficiency was identified. This could be due to several reasons: The model boundary may be too narrow or no controlling loop may exist at the local level, or this structure is missing in the model. However, Chapter 6.1.3 and the concluding remarks suggest some indicators that would help establish a monitoring loop on environmental effectiveness of the recycling initiative.

Main issue	Important loops	Main factors and effects determining the strength of the loops	Personal and contextual factors influencing the strength of the effect on the loops	Underlying theoretical concepts
Compliance	"Getting disappointed"	• Effect of burning cost • Effect of crowding	• Capacity in collecting point • Garbage bag charge • Acceptable unit cost for burning • Perceived social norm for burning	• Opportunity cost • Planned behavior • Non-price-mediated resource allocation • Planned behavior (choice concept)
	"Getting motivated"	• Fraction becoming willing from social norm separating • Effect of time cost separating	• Perceived social norm separating • Acceptable time for separating (Max acceptable separating time) • Time spent for separating (effective nr recycling streams, normal time per stream)	
Environ-mental effective-ness	No controlling loop!	Underlying theoretical concepts • Habits • Separation capacity of citizens • Sufficiency strategy (self-modification strategies) • Efficiency strategy • Technological innovation • Consistency-principle		
Economic rational	"Less burning increase price"	• Number people separating • Zero deficit budget policy	• Price policy of community (cross subsidizing, price adjustment delays, base tax)	• Economic incentives • Polluter pay principle • Cross subsidizing effect • Cost recovery and break-even point
	"Less burning reduces cost"	• Number people separating • Cost that should be covered by bag charge • Zero profit budget policy	• Incineration cost per unit • Unit cost for collecting burnable material • Total amount disposed for burning	
	"More separation increases cost"	• Cost that should be covered by bag charge • Zero deficit budget policy	• Capacity in collecting points • Total amount separated	

Table 6.1: Key loops and key factors explaining recycling dynamics.

Summing-up, the shift in perspective gives evidence that the significance of the preconditions depends on the loop dominance. Driving forces in the systems are the dynamics and not single factors. Identifying the dominant loop in the system may be seen as an important precondition for effective policy intervention. Secondly, we have seen that personal precondition may be an important intervention point in unfavorable contextual recycling conditions reinforcing the **"getting motivated"** loop. This gives further evidence for the relevance of changes in preferences explaining policy outcome.

It is noteworthy to interpret the findings under the managerial perspective, which focuses on the design, control and development of the solid waste management system (Ulrich 1984). The overview about the controlling loops in solid waste management in Table 6.1 shows that a monitoring system only oriented towards profitability is insufficient. As

highlighted in Section 5.6.3 and 5.6.8 the internal dynamics of an effective garbage bag charge policy and the countervailing price effect of a prepaid tax policy may lead to a trade off between the policy effectiveness and a zero profit budget, measuring the efficiency of the policy. Even worse, managing the local solid waste system oriented toward a zero profit budget may lead to failure of the recycling initiative – since the dominance of the **"getting disappointed"** loop would lead to a profit. Also the scenario-experiments have shown that in worst-case conditions "counterintuitive decision" would be required to avoid failure of the recycling initiative. Why would the localities increase the garbage bag charge if they were already running a profitable solid waste management program?

These insights indicate that having a management and controlling instrument that is adequate for controlling a dynamically complex system such as the solid waste system is essential. The deficit of established theories of management are recognized in the literature. With the help of a SD management-model, Schwaninger (2002) showed that "the power of orientation furnished by established theories of management is only strong with respect to the short-term horizon; until recently they had little solid to say concerning the long run"(3). In addition, he suggests a conceptual framework for a systemic management, which copes with the challenge of dynamic complexity, called "Framework for Systemic Control" (for example, Schwaninger 2001). It is based in Systems Theory and Cybernetics and offers a management-cybernetic theory of pre-control that helps balance economic, ecological and social goals in a system. It is based on the insights "that a system must govern itself by means of control variables that may contradict one another, because they belong to different logical levels: the levels of operative, strategic and normative management" (Schwaninger 2001:1213).

Those innovative views on management may also be highly relevant to solid waste management at the local level for different reasons. Firstly, Table 6.1 points out that in the current solid waste model, feedback loops for controlling the environmental effectiveness are missing. Secondly, the policy-experiments illustrated that profit as a performance-indicator could contradict indicators measuring environmental effectiveness. Finally, Section 6.1.5 (Concluding remarks on policy implications) emphasizes the need for control variables that helps develop the solid waste management system in such a way that it fulfils the claims of all relevant stakeholders (for example citizens or recycling corporations), in order to create competitive recycling markets.

As observed earlier, solid waste management is more than just being a waste management business since it also induces behavior change in the overall system. For this purpose not only a profound system understanding is required but also an integral and systemic management model that helps managing and balancing the crucial control variables on all three logical levels of operative, strategic and normative management is essential.

Elaborating on such a solid waste management system is beyond this study. But this study served the twin purposes of identifying important deficits of the practical solid waste management and also paving the way towards development of a model of systemic solid waste management that are grounded in general frameworks of systemic control (for example, Schwaninger 2000).

6.4   Reflections on the study and the research approach

The reflections on the study and the research approach focus on the frameworks developed and used in this study, its strengths and limitations and the broader implications of its results.

6.4.1   Reflections on the frameworks

This study resulted in a dynamic theory that explains observed behavior patterns of indicator-variables from local solid waste management. It can also be used as a scientifically grounded decision support system that informs the debate on policy-design in solid waste management. Enhancing a problem-oriented knowledge transfer towards decision-makers was one important motivation for this investigation. Therefore, throughout the study the different insights were organized and structured in frameworks serving as a heuristic for both the investigation and for policy design.

A heuristic is seen as a device that helps generate new insights and/or tackle problems (see Schepers 1974, Lorenz, 1984). According to Schwaninger (1997:113) it can best be translated as "the art of finding", while Beer (1990) emphasizes the inherent evaluative process according to some known criteria (402). Zaugg (2002) highlights the function of frameworks as heuristics in an explorative research approach. They serve as a systematic "idea-memory" accumulating and organizing new blocks of insights.

In this research approach the different frameworks are crucial elements. Therefore, this section will reflect on them in order to shed some light on the frameworks' significance. For this purpose we will refer to the criteria for evaluating theories suggested by Bacharach (1989) and on the types of frameworks in explorative research identified by Zaugg (2002).

According to Zaugg (2002) different kinds of frameworks come along with the steps of theory development. Consequently, he distinguishes four kinds of frameworks: the term frame, the description frame, the causality frame and the decision frame. The **term-frame** defines the main terms that are used in order to describe and analyze the issue. The **description-frame** imposes the main components of the object under investigation, puts them in a first order and defines the boundary. It gives the investigation a first direction. This framework helps generate concrete research questions. The **causality-frame** substantiates stated causal relationships that can be falsified. First implications can be derived that contribute to solving the problem addressed. The **decision-frame** is the final product that arranges the problem-situations and allows generating conclusive recommendations.

While this distinction may be seen as ideal, some analogies in the development and function of the frameworks of this study are seen. Table 6.2 gives an overview of the developed and applied frameworks and tries to assign them to those introduced by Zaugg (2002). It is indicated in the column "Functions of frameworks".

Bacharach (1989) offers a different distinction of modes of analysis. He distinguishes theories - addressing how-, why-, and when –questions - from three different modes of description: categorization of raw data, typologies and metaphors. **Categorical analysis** specifies a phenomenon and **typologies** focus on the important characteristics of the phenomena. Both modes of analysis answer what-questions. Those descriptions may be the source material of theories. The third mode of description is a **metaphor**. It can be used to describe how the phenomenon under investigation is similar to another better-known phenomenon. Bacharach (1989) emphasizes that "a metaphor must go beyond description and be a useful heuristic device. That is, the imagery contained in the metaphor must assist the theorist in deriving specific propositions and/or hypotheses about the phenomenon being studied"(497). The adequacy of the image is less important than its power to evoke plausible propositions and hypothesis enhancing theory building. According to Bacharach (1989) a theory is "a system of constructs and variables in which the constructs are related to each other by propositions and the variables are related to each other by hypotheses. The whole system is bounded by the theorist's assumptions, ... " (498).

While Bacharach aimed at clarifying "what a theory is and what not", the distinction helps clarify the status of frameworks used in this study. The Table 6.2 shows its assignment in the column "Modes of description".

Chapter	Frameworks	Description	Derived from / sources	Modes of description	Functions of frameworks
3.1.1	A List of Important Criteria for Public Policy	The framework presents a list of important criteria in order to improve contextual or personal preconditions for ESA.	Derived from previous research on ESA from the SPPE	What are crucial preconditions? What are their crucial characteristics? **Characteristics of a categorical analysis**	Term frame
3.7 / 5.2	A Feedback Perspective on Human Behavior and Public Policy	The framework illustrates the feedback perspective that is guiding the system analytical investigation. It focuses on contextual and personal structures. Intervention points for the different types of policy instruments are indicated.	Elaborated within the IP "Strategies and Instruments".	How is the phenomenon similar to another phenomenon? The interaction between human behavior and public behavior is seen as a feedback-control-system that refers to servomechanisms. **Characteristics of a metaphor**	Causality frame
5.1	Framework Model REB	The framework presents the ten identified clusters of key variables influencing intention. It clarifies the relationship to the hierarchical subsystems "household consumption patterns" and "household metabolism".	Synthesized from the mental models of experts of the system under study.	What is the most important aspect of the phenomenon? What are the driving forces that cause the observed patterns? **Can not be assigned to the suggested modes of description**	Description frame
5.1	A Practical Guide for Facilitating Environmental Policy Compliance	The framework terms clusters of key variables of ESA and specifies their relations to the identified supportive preconditions, as well as bears the direction of impact of the clusters	In this framework the findings of the previous research on ESA and the analysis of the mental model of the systems experts are combined.	Key variables are termed and clustered as well as characterized in relation to the observed phenomena. **Characteristics of typology**	Causality frame
5.3.3	Overall model structure	This framework describes the overall SD-SWM-model structure and visualizes the main stated relationships between the different model sectors.	This framework is a product of the model conceptualization-process.	The most important sectors and components, as well as main relations are pointed out. **Can not be assigned to the suggested modes of description**	Causality frame
5.2 - 6	The SD-SWM-model	The model represents on the one hand a computer based learning environment that both highlights the interplay of contextual and personal factors in solid waste management and helps to analyze the impact of different policies and solid waste management strategies. On the other hand it represents a dynamic theory for local recycling dynamics.	Grounded in theoretical and empirical findings and developed in the regenerative explorative research approach.	The primary goal is to answer theoretical questions of how, when, and why did the phenomena evolve? It is a system of variables that are related to each other by hypotheses. **Is a dynamic theory**	Explanation and decision frame

Table 6.2: Overview of used frameworks and their assigned functions.

Bacharach's distinction of modes of analysis is only partly suited to situate the different frameworks of this study. However, it is useful to identify a "real" theory. In sum, this presentation of the frameworks partly clarifies their significance in the research process. It does not only clarify the different grades of the frameworks but also indicates the different milestones that have been passed on the way to theory building. It is evident that only the SD-SWM model can be classified as a theory. While Zaugg's classification suggests that recommendations should only be derived from explanation and decision frames, Bacharach's distinction does not make a clear statement about their role in the application context. However, because some frameworks are more general than the SD-SWM-model (e.g. *"the Feedback Perspective on Human Behavior and Public Policy"* or *"a Practical Guide for Facilitating Environmental Policy Compliance"*) they may also be useful for decision-makers as decision support tools, in addition to the simulation model.

In addition this overview illustrates that "the art of finding" applied in this study was a systematic process resulting in some promising general frameworks that could be used for further investigations and as supplementary decision support tools.

6.4.2 Strengths and limitations

The following section will discuss some specific strengths and limitations of this study and the SD-SWM-model.

Some noteworthy strengths are as follows:

- This study applies the Integrative Systems Methodology. Referring to the methodological framework facilitates comparison, positioning and evaluation of this investigation for other researchers. Analysis of preconditions of ESA illustrated the relevance of the context-loop in order to grasp the real causes of policy resistance and implementation problems that evolved in solid waste management. As the different frameworks show, strong weight was placed on the modeling-phase including the preliminary study and parts of the main study. The development of reference-frameworks as a substitute for a disciplinary focus proved to be fruitful and may become a crucial element in Integrative Systems Methodology.

- The substantial policy implications derived give evidence that System Dynamics was an excellent choice to tackle the highly complex issue of this investigation – such as the internal dynamics that caused both the recurrent deficit in solid waste management as well as the growth in the *<fraction separated>* and the "first-worse before-better" behavior pattern in impurity.

- The development of the SD-SWM-model can be retraced. Its theoretical grounding and its premises are made clear. It was guided by strong empirical and theoretical evidence. The SD-SWM-model is clearly described and documented in this book.

- Important insights about interactions of personal and contextual factors and important intervention points were identified. Furthermore, the effectiveness of different policy-packages could be tested.

- The SD-SWM-model is relatively simple and is therefore, suitable for the purpose of enhancing the understanding of how important personal and contextual structures cause internal dynamics and produce the observed behavior pattern.

- The model has been carefully tested, and different sensitivity analyses were conducted. The test results give evidence of its robustness and consistency as well as correspondence.

- The System Dynamics modeling syntax allows evaluating the SD-SWM-model as a theory applying general criteria for evaluation theories such as suggested by Bacharach (1989). A systematic critique of the theory will be beyond this study but could be done by other researchers pushing the debate of computer-assisted theory building further. Furthermore, the concepts and constructs included in the model (such a habits, preferences, social norms, planned behavior) may help bridge the gap between other theories and suggest refinements of pre-existing theories.

In addition to the aforementioned strengths of this study, six main limitations were identified:

- The overall research approach was very time-consuming and challenging. Firstly, the demand to tackle the issue rather comprehensively requires a broad knowledge of different theories from different disciplines and good synthesizing skills. Secondly, System Dynamics and its analytical tools have to be well understood in order to achieve promising results. Besides system analytical understanding, system thinking and modeling must be trained with the help of experienced coaches. In addition, working with the audience and applying the techniques of Group Model Building requires further skills, that cannot be easily learnt (e.g. group process structuring skills). In order to keep the task feasible for one researcher, the actual model formulation did not include the audience. Therefore, the mutual learning process was interrupted and the insights have to be shared with them separately. This will probably affect the overall effectiveness of this investigation.

- The design of other desirable policy experiments and further SWM-strategies still needs to be discussed with the audience and simulated with the model. This will probably require some adjustments to the model structure. Especially, the model structure has to be enriched in order to be suitable for simulating and investigating waste avoiding strategies and policies.

- The SD-SWM-model could still be improved. Furthermore, the parameters and graphical functions need to be empirically substantiated (see Section 7.2.1 and 7.2.2).

- The SD-SWM-model cannot be used to address detailed issues of policy implementation such as a decision aid about which communication instrument to

choose. Furthermore, it cannot be used for precise prediction of the outcomes of a policy intervention at a specific year.

- It is important to emphasize that the policy conclusion bears not only the methodological meta-assumption (see Andersen 1980) but also the modeler's own assumptions made in the model building process. Furthermore, the applicability of the model is bounded to the specific family of solid waste management systems dealing with recycling dynamics. However, the model includes some generic structure components that could be used as building blocks in other contexts of applications.

- The interdisciplinary approach that addresses the real problem from different perspectives and theories includes both compatibility issues and issues of scientific quality related to the depth of theoretical knowledge (e.g. a critical appraisal is missing) – and the review can mainly focus on general well-founded theories and assumptions. In general, the interdisciplinary approach have to compromise on depth of disciplinary theory appraisal since mastering the scope of relevant literature becomes challenging. Furthermore, the interdisciplinary approach complicates the establishment and determination of a clear field of expertise of the researcher.

Although this study has some specific limitations, it demonstrates an innovative approach to environmental policy analysis and public management that focuses on loops as causes of behavior and traces the loop dominance back to personal and contextual factors. Therefore, it provides a broader basis for policy analysis and policy-making as well as public management, since it increases the variety of interventions and implementation options and helps to identify advanced warning indicators.

7   Conclusions and future directions for research

"One way to change a paradigm is to model a system, which takes you outside the system and forces you to see it whole" (Donella H. Meadows, 1997).

This chapter summarizes the main insights and findings and gives directions for future research. A comprehensive summary and discussion of the insights has been given earlier after each Chapter of the various policy-experiments (Sections 5.6.2, 5.6.4, 5.6.6, 5.6.8) and in Chapter 6 (Discussion and reflections on policy, theory and method). However, in this Chapter, key insights from this study are presented as "take home messages" for practitioners and researchers. Suggestions for future research are given both for solid waste management issues and general issues of policy analysis.

7.1   Main insights and findings

7.1.1   Take home messages for practitioners

The main insights from the system dynamics view on solid waste management for policy-makers and practitioners are summarized in five points.

1. Have the right mental model of the system and understand the motivation for policy compliance. A simple diffusion model can explain the success or failure of a recycling initiative. The main challenge of practitioners at the local level is to implement robust recycling-strategies. For this purpose policy-instruments that act on the factors reinforcing the diffusion process and motivate people to separate their waste are crucial. The following main triggers are identified:

- Preferences for waste separation (dependent on the perceived norm for separating): Waste separation must be perceived as the right thing to do. The immediate context of behavior, especially in public places should present option and action possibility and subsequently invite for waste separation actions. Signs of model waste separation behavior should be pointed out.

- Time cost for separation (related to alternative cost of burning, and preferences for waste separation): Waste separation should be perceived as convenient and rewarding in every context of behavior.

Factors such as garbage bag charge, high quality of separation, adequate collecting services and perceived success of the recycling initiative that prevent people form getting disappointed by waste separation are important. Such "messages" weaken the norm that putting waste for burning is the "normal" thing to do.

Being aware of both acting forces, i.e., getting motivated and getting disappointed and their dynamics is important. Hence, at the local level not only *economic instruments* but also

communication and diffusion instruments as well as *service and infrastructure instruments* become important in order to ensure the success of a recycling initiative, especially in adverse conditions. The observed impurity and the actual fraction separated depend on the state of the adoption process of the recycling initiatives and on the disposal habits of different groups of people in a community.

2. Understand the economic trade-offs and apply the appropriate public management paradigm. Garbage bag charges are the alternative cost of time cost for waste separation behavior. In order to be effective they need to pay off the time cost of waste separation. However, for the economic rationale of organizations dealing with solid waste, important trade-offs must be considered.

Firstly, a garbage bag charge leads to a smaller amount of waste disposed for burning. As intended, this would decrease the cost for solid waste management (ceteris paribus). But conversely, hidden cross-subsidies and the shift in the amounts of waste disposed for burning and for recycling would lead to higher garbage bag charges. Hence, an initially set garbage bag charge tends to underpay the variable cost of solid waste management services. In addition, a further growth in the waste generation per capita reinforces the tendency of an insufficient cost recovery of a successful recycling initiative. Consequently, due to the internal dynamics no well-defined equilibrium price for the garbage bag charge exists and price adjustment delays will lead to a recurrent deficit. Finally, an effective garbage bag charge policy increases not only the total amount of separated material but also the cost of solid waste management. Hence, the working hypothesis stated in the very beginning of this work "if more citizens develop environmentally sound behavior patterns then local decision makers will face reduced cost" has to be rejected from a short-term perspective.

In sum, internal dynamics lead to important trade-offs that undermine the simple economic rationale of cost recovery and break-even policy, as well as of a partial polluter pay principle. Hence, those management principles are insufficient for inducing environmentally sound disposal patterns of citizens and could lead to functional government failure (Feser 1996). Although a cost covering provision of public services is an important objective, it should not be the only guiding paradigm of public management. The legitimacy of public solid waste management comes from the paradigm of sustainable development, efficient environment and natural resource management. Hence, the traditional accounting model alone cannot be used as a decision-aid for effective policy design. For this purpose the SD-SWM-model is more appropriate, since it highlights the different trade-offs and long-term dynamics.

Indeed, it emphasizes that solid waste management can and must activate multiple triggers for a turn around in solid waste management. According to this rationale, a high service quality in solid waste management that aim at saving natural resources (waste reduction) and reaching recovery goals (waste recovery), complemented by a public deficit guaranty supporting competitive prices for separated waste may be indicated. In the long run this multidimensional approach is more suitable for adding public value.

Also, this line of thinking is more adequate to legitimize a PUBLIC solid waste management system than insufficient pollution pay and break-even principles. Hence, the SD-SWM-tool may be especially suitable as a decision support tool for local governments that aim at enhancing market developments for environmentally sound services and products and feel responsible for equity, service quality and competitive prices in solid waste management.

3. For offering collecting points, collaborate with retailers and give further incentives for citizens' waste separation behavior. The main weakness of prepaid taxes - when they are hidden - is the lack of incentives to motivate people to separate their waste. Under a prepaid tax regime the quality and quantity of *collecting services*, as well as *communication and diffusion instruments* remain crucial or may become even more important. In addition, due to the countervailing price effect, an ineffective policy tends to lead to profit in the local solid waste management. In such a situation only higher financial incentives may help turn around a failing recycling initiative under a prepaid tax policy. According to a break-even budget principle this implication would be counterintuitive.

These considerations suggest that retailers may become important providers of additional collecting points put they cannot replace further recycling initiatives and collecting services provided by local authorities. This indicates that a single actor cannot contribute to improve solid waste management but that it must become a task for multiple actors in the system.

4. Understand the limits of the recovering strategy "offering different recycling streams and investing in citizens' waste separation capacity". Stay within the bounds of citizens' compliance-capacity. The separation strategy "offering for every recyclable material a separate recycling stream" is cost efficient for the overall solid waste management system when it does not exceed citizens' capacity to separate. Overwhelming citizens' separation capacity pushes the system over the tipping point and leads to failure of the recycling initiative. The limit of a recycling strategy depends on the maximal number of people that can become willing to separate their waste, their separation habits, as well as the inherent fraction recyclable material in waste.

5. Elaborate on and apply an adequate navigation model for solid waste management. As we have seen above, the practical economics based navigation system in solid waste management is insufficient. In order to steer the dynamically complex solid waste management system in the desired direction, a systemic, comprehensive controlling model is required that gives information on the actual state of limiting factors of the diffusion of a recycling initiative and its environmental effectiveness. It should monitor the potential capacity of the citizens to separate and those of the recycling industry, as well as the development of recycling market and the relative prices of the secondary raw material and the primary raw material.

7.1.2   Relevant lessons for researchers

Besides those insights that are of practical relevance, this study provides some lessons on exploring and investigating multifaceted, dynamically complex issues that may also be relevant to other researchers.

   1. Frameworks help manage the relevant body of knowledge. Identifying relevant knowledge and helpful disciplinary concepts is an iterative research-process. In this process, frameworks may serve as scientifically grounded "idea-tanks". They help in the integration of different disciplinary perspectives and help organize blocks of insights, as well as structure the issue. Most importantly, they render the "Art of Finding" in a documented systematic process.

   2. Apply a unifying perspective that helps structure the problem focus. The feedback and system view proved to be helpful in shaping the field of investigation and integrating different perspectives as well as exploring relationships between different system components. *"The Feedback Perspective on Human Behavior and Public Policy"* visualizes the basic controlling loop between internal and contextual factors that is guiding future actions of either people or of organizations. It illuminates the role of interactions between information processing and goals as well as the creation of action possibilities and constraints. It may serve as a consistent research heuristic that helps conceptualize the system under focus as well as to identify and focus on important system components.

   3. Choose the adequate methodology that helps analyze dynamically complex issues. A further ingredient is choosing a methodology that helps dealing with multifaceted and dynamically complex issues. The applied Integrative Systems Methodology offers a unique reference methodology that allows combining research approaches based in different paradigms. The concrete applied System Dynamics approach including qualitative elements of Group Model Building proved to be useful for the development of an insightful dynamic theory on recycling dynamics. The quantitative model building process helps identifying and integrating useful disciplinary concepts and findings in order to develop an adequate decision support tool. Furthermore, micro-processes that explain macro-processes can be modeled and tested. Having this focus on policy and management issues, the processes between the different system components become more important than the component, itself.

   4. Master the crux of policy implementation and policy resistance. The specific focus on personal and concrete contextual variables in the decisions rules of the model provides a broader basis for policy analysis. It opens up richer intervention and implementation options for local authorities, which is fundamental for coping with complexity, according to Ashby's Law of Requisite Variety (Ashby, 1956). Furthermore, focusing on the interplay between contextual and personal factors is crucial in order to understand the phenomenon of policy resistance. In addition, it points out important system

requirements in order to reach high policy compliance. There may be a lot of "sand" in the "mechanism"; however, for efficiency reasons it is important to recognize the dominant processes guiding policy compliance.

5. Lessons on environmental policy and management in a nutshell. The model gives evidence that the interactions and impact of different policies depend on the concrete situation - the pertinent contextual and personal factors of a behavior setting. When sensitive policy parameters of the systems are identified, knowledge of the mode of functioning of different instruments is seen as highly relevant in order to choose the most effective policy-package. This observation substantiates the statement that no generally optimal policy mix would exist. But it also gives guidelines on designing those for the specific case.

Furthermore, the key-loop perspective on the solid waste management system suggests that a systemic managerial perspective on public policy is necessary in order to identify and control the driving forces in the system. Hence, the SD-SWM-model gives evidence that local authorities can steer and fine-tune the system performance from bottom up – provided that they have adequate management-models and controlling instruments.

7.2   Suggestions for future research

In the next two sections directions for future research aiming at elaborating on the suggested SD-SWM-model are outlined.

7.2.1   Model improvements

The model tests and the policy-experiments give confidence in the correspondence and robustness of the model behavior. The model suits the purpose of this study. However, the model can still be improved. One meaningful way towards model improvement is seen in testing its usefulness and usability for the audience in an application context. Probably some adjustment of the user-interface such as the elaboration of a policy-cockpit could be helpful. Furthermore, the model audience may stimulate testing further policy-options. Such additional tests could require adjustments in the model structure. More specifically, the insights of policy-experiments **implement price for burning and separated material** could become more meaningful, if waste generation and reduction decisions would be modeled endogenously. This would allow testing waste reduction-policies. Finally, additional confidence in the model could be gained by grounding modeler-defined parameters and look-up functions on bases of empirical data or by eliciting them directly from the experts of the systems.

However, those adjustments would probably only bring minor additional insights. A more promising research direction is seen in a further development of the model that would be guided by new policy and management issues.

7.2.2   Further development of the model

This study offers different starting points for a further development of the SD-SWM-model. Three directions are presented below.

1. Development of a micro-world for capacity adjustment. The sector diagram depicted in Figure 5.9 and Figure 5.16 conceptualize an enlarged SD-SWM-model that would allow addressing recycling markets issues and the dynamics of capacity adjustment processes. Such an enlarged micro-world would be especially meaningful for informing incineration and recycling capacity investment decisions. In addition different secondary-raw-material recovering strategies could be tested, for example one that builds on the separation capacity of citizens and alternatively, one that builds on the separation capacity of the recycling sector.

2. Development of a comprehensive natural resource management model. A second promising direction for further model development is seen in the ambition of building a comprehensive natural resource management model that includes firstly, capacity planning and financing sectors, as suggested by Mashayekhi (1988), and secondly, includes a market development policy-sector with different information environments, as suggested by Randers and Meadows (1973) and by Chung (1992). Such an extended SD-model would represent a national resource management model. It would allow testing the dynamics of material and energy intensity, as well as the standard of living in an economy under different environmental regulations, information policies and market development policies. However, such a model project must be carefully conceptualized to ensure that it is feasible and insightful. Furthermore, it should be transferable to different countries.

Both suggested directions for further model development would offer a dynamic theory for the issue at hand and would serve as a micro-world for conducting policy experiments under well-defined conditions. The purpose of the model would be to offer a virtual world to aid learning and policy design (Sterman 2000). However, as emphasized in Chapter 6.3, having an adequate model and understanding of the dynamics in a system may not be sufficient in order to steer the development of the system in the desired direction. This assumption is in line with Richardson's (1994) operator logic hypothesis. It suggests that "system interventions focused on understanding detailed system structure will have little impact if they are not captured in easy-to-digest chunks of strategic insights that managers can integrate into relatively simple means-ends associations"[1].

Instead of suggesting an investigation of this hypothesis, this study provides evidence for the importance of a systemic control instrument that helps assess, steer and design the development process of a system.

3. Development of a systemic navigation model for solid waste management.

Hence, the third suggestion for a further model development is to elaborate on a navigation-model that is guided by the framework for systemic control (see for example, Schwaninger 2002) and to assess it in the application context.

Such a model would probably include feedback loops assessing the environmental effectiveness of a policy-package as well as pre-control variables as suggested in Chapter 6.1.5. The model of Wäger and Hilty (2002) illustrates some promising starting points for assessing and controlling the environmental effectiveness of solid waste management policies. Furthermore, such a navigation model would include all the essential variables[68] that help assess system performance on all three logical levels of management (on the normative, the strategic and the operational management level). In addition, the actual state of a development or "diffusion" process could be evaluated. For scholars this suggests that developing such a sophisticated solid waste navigation model would represents a significant opportunity to improve management and policy practice.

7.2.3   Ideas for further theory development on public policy issues

In this last section some research opportunities for theory building in public policy will be outlined. For this purpose we step back from the concrete management issues at hand, taking a more abstract view of the study.

Chapter 3.2 pointed out that the study aimed at exploiting some of the research opportunities identified by Stern (2000) and by Vlek (2000): investigating both interactive effects of personal and situational variables, as well as environmental policy formation and decision-making.

Although some substantial insights could be gained on those issues, this study can only be seen as a promising first step in this direction of research. This study suggests that the interactive effects of personal (such as willingness to invest time in a specific behavior or habits) and situational variables are important for understanding the effectiveness of policy initiatives. Understanding the processes that help unfreeze harmful habits and establish new ones represents a significant opportunity for improving policy effectiveness and breaking path dependency in a system.

Furthermore, focusing on the essential variables and the dominant loops that control the decision points in a system may help understand policy resistance. Investigating compliance behavior and the driving factors and their interactions as suggested by Winter (2001) will be even more important for designing policy-packages that correspond to the actors' motivation and capacity for policy compliance.

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[68] According to R. Ashby (1960) essential variables are those "which are closely related to the survival (of the system under study) and which are closely linked dynamically so that marked changes in any one leads sooner or later to marked changes in the others" (42), (cited in Schwaninger 2003a).

With regard to the specific case of recycling dynamics a micro choice structure for citizens' separation behavior is suggested. However, further research is required in order to synthesize a choice structure that can be generalized for other contexts of applications. This line of research could found a generic SD structure of choice, e.g., related to policy compliance issues.

Beer (1966, 1990), on his way towards the Viable System Model (V.S.M.), developed a methodology of topological maps that could also be useful to analyzes the SD-choice structure. The aim of such an approach could be to suggest a generalized SD-Compliance-Choice structure based on the framework *"a Feedback Perspective on Human Behavior and Public Policy"*. The framework could serve as a basis for describing the scientific situation of a concrete problem statement.

Figure 7.1 illustrates Beer's methodology of topological maps and its account of scientific modeling. At the heart of his methodology is the identification of similarities between two different systems. In the following paragraph the philosophy of science of Beer's methodology of topological maps will be briefly drafted..
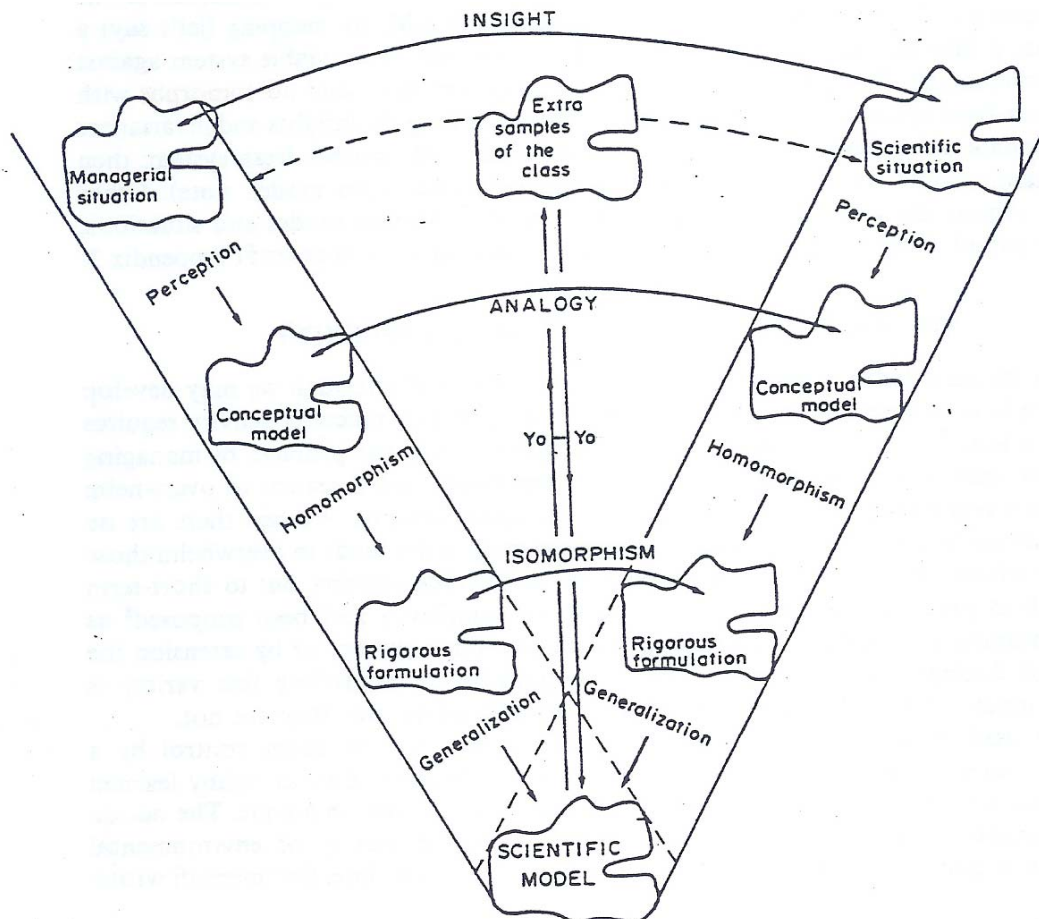
Figure 7.1 Beer's methodology of topological maps and scientific modeling (Beer, S. "The Viable System Model: Its Provenance, Development, Methodology and Pathology". Journal of the Operational Research Society 35(1), 1984:9, Copyright 2004, reproduced with permission of Palgrave Macmillan). At the level of the conceptual model[69] of the managerial and the scientific situation an analogy exits between them. Each is then mapped homomorphic on to a

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[69] see also footnote 68.

rigorous mathematical formulation having a isomorphic relationship to each other concerning the structure and the behavior; hence, representing a scientific model (see Beer 1966).

In the search of analogies between two systems and in the process of formulating the conceptual model, a generic scientific model, or a generalized system, or a generic structure will be identified that is characterized by homomorphic and isomorphic mapping.

Homomorphism[70]: a mathematically many to one mapping which preserves the operation. For example all citizens' compliance behavior follows the same law not only the observed sample, but also all organizations' compliance behavior would follow a unique law.

Isomorphism: a mathematically one to one[71] invariance between two different systems, for example, if the unique citizens' compliance law would be unambiguously the same as the unique organizations' compliance law.

Beer (1984) describes homomorphic and isomorphic mapping as follows:

"The process continues, and begins to have the marks of a scientific method, when we try to develop rigorous formulations of the two conceptual models. These will be homomorphic mapping, insofar as many elements in the system that is conceptually modeled will map onto one element in a rigorous model. ... If we find invariances between two systems, then these are isomorphic mappings, one to one in the elements selected as typifying systemic behavior in some selected but important way" (8).

His methodology suggests that modeling general compliance issues of different cases could be a promising approach in order to come up with a generic model applicable to issues of citizens', consumers', firms', or organizations' policy compliance (for a comprehensive description of his methodology see Beer (1966:106-119)).

7.3   Afterthought on managing for sustainable development

This book concludes with a short afterthought. We will step back a little bit further in order to oversea the whole work and to tie what was said in the beginning to what is being said at the end. This work grew out of the global spirit of sustainable development. Hence, the working title of the main study was "Managing for Sustainability: A Decision Support Model for Solid Waste Management". In order to understand the full meaning of this overarching title, it is helpful to bring to mind the meaning of the term sustainable development. In the terminology of the United Nations a *sustainable development* embodies a global, regional and national development of the society that aims both to meet the (basic) needs / preferences

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[70] Homomorphism is a map from one group to another but the operation is preserved; normally, in doing so the information is reduced. Relating to informatics the conceptual model may be seen as the source system which defines the variables, their connections to the "real world " and assigns sets of allowed values. "A Source system already specifies what aspects of the "real world " are important, where "important" must always be seen in the problem context of our system. Also specified are how to map these aspects into our space. This is normally a homomorphic mapping – the values are simplified and less in number, but the "relevant" structure is preserved (http://www-lehre.informatik.uni-osnabrueck.de/~ftprang/papers/tproject/node4.html, visited July 2, 2004).

[71] Pairing each element of a set uniquely with an element of another set

of all human beings, now and in the future as well as to enable them a good life (gutes Leben), according to Di Giulio (2004). This understanding illustrates that managing for sustainability includes the task of meet the preferences of stakeholders such as citizens of the present and future. Hence, a long-term perspective and an inter generation contract is required.

Taking into account the preferences of the present stakeholders is crucial for high policy compliance, as we have seen in the suggested SD-SWM-model. Furthermore, the model emphasizes the interactions between public policies and the development of preferences. In addition, there are also interactions between financial management and public policies. In sum the SD-SWM-model facilitated a better understanding of the main loops that are responsible for the observed dynamics and trade-offs in the solid waste management system. Managing such dynamically complex processes is a major challenge for practitioners. In addition, under the paradigm of sustainable development local authorities become important agents for a change process in society shaping not only the physical behavior setting but also informal constructs and structures of reality such as social norms, habits or life styles. Subsequently, managing for sustainability requires enforcing or creating processes that are desirable for sustainable development and slowing or correcting undesirable processes (Schwaninger 2003b).

The global appeal for sustainability is an appeal for a paradigm change also in solid waste management. By offering a micro-world, this work tries to take scholars and practitioners outside the system and forces them to see it as a whole and recognize the processes that drive the development of the system. This may be seen as an important step in triggering a paradigm change towards managing virtuous and vicious circles away from a simple one-dimensional causality thinking and "problem-plan-action" management philosophy.

Having this hope, the final thought of this work can be summarized in the following assessment.

The whole of this work is nothing more than an approach to the refinement of everyday managerial thinking in such a way that it helps to cope with the challenge of a sustainable development.

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Appendix

A Model structure, equations and parameters

A1 Overview model structure

View 01 "Back-casting policy-experiments 1987"

View 02 "Forecasting policy-experiments 2004-2020"
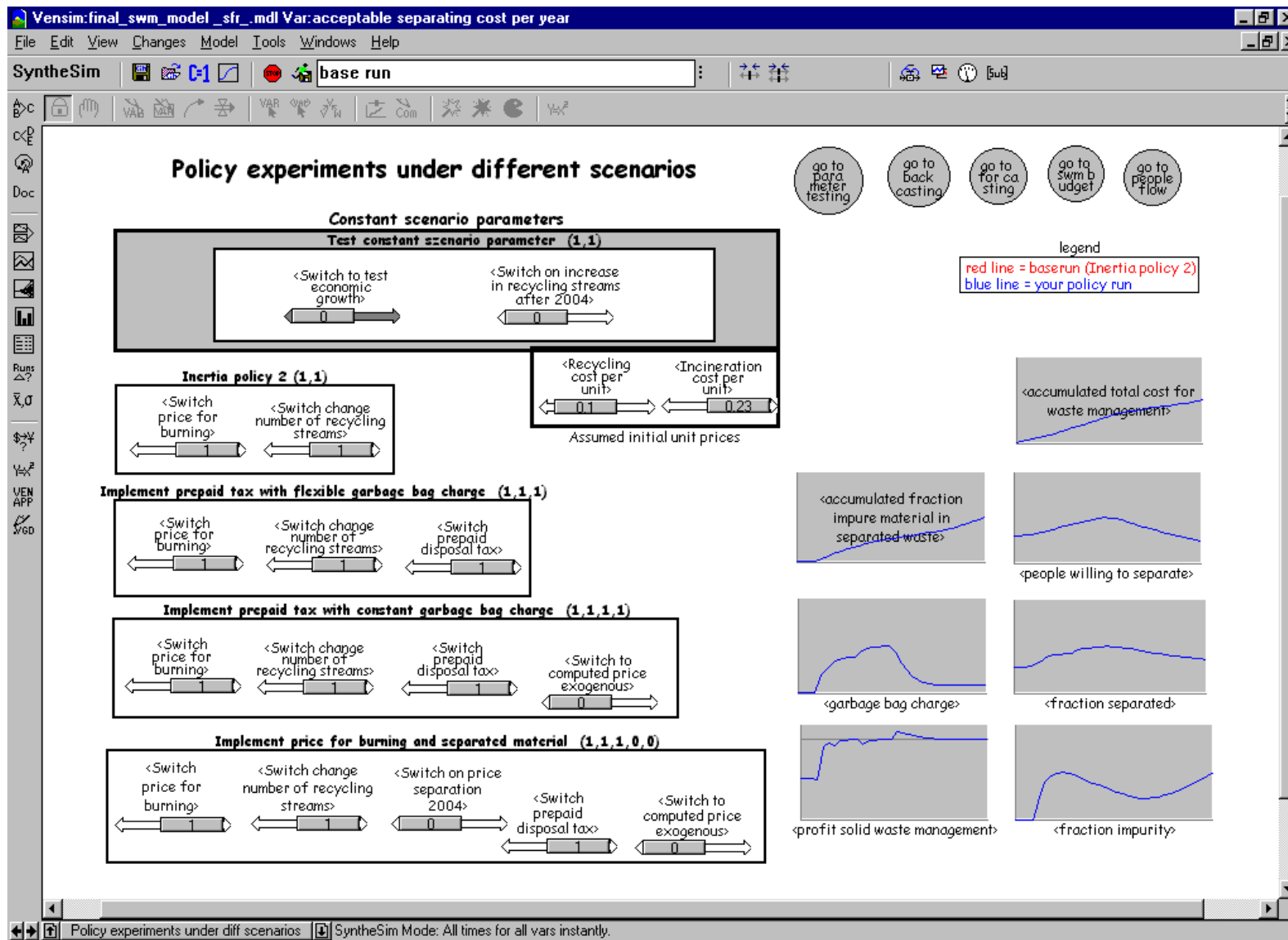
View 03 "Policy-experiments under diff scenarios"
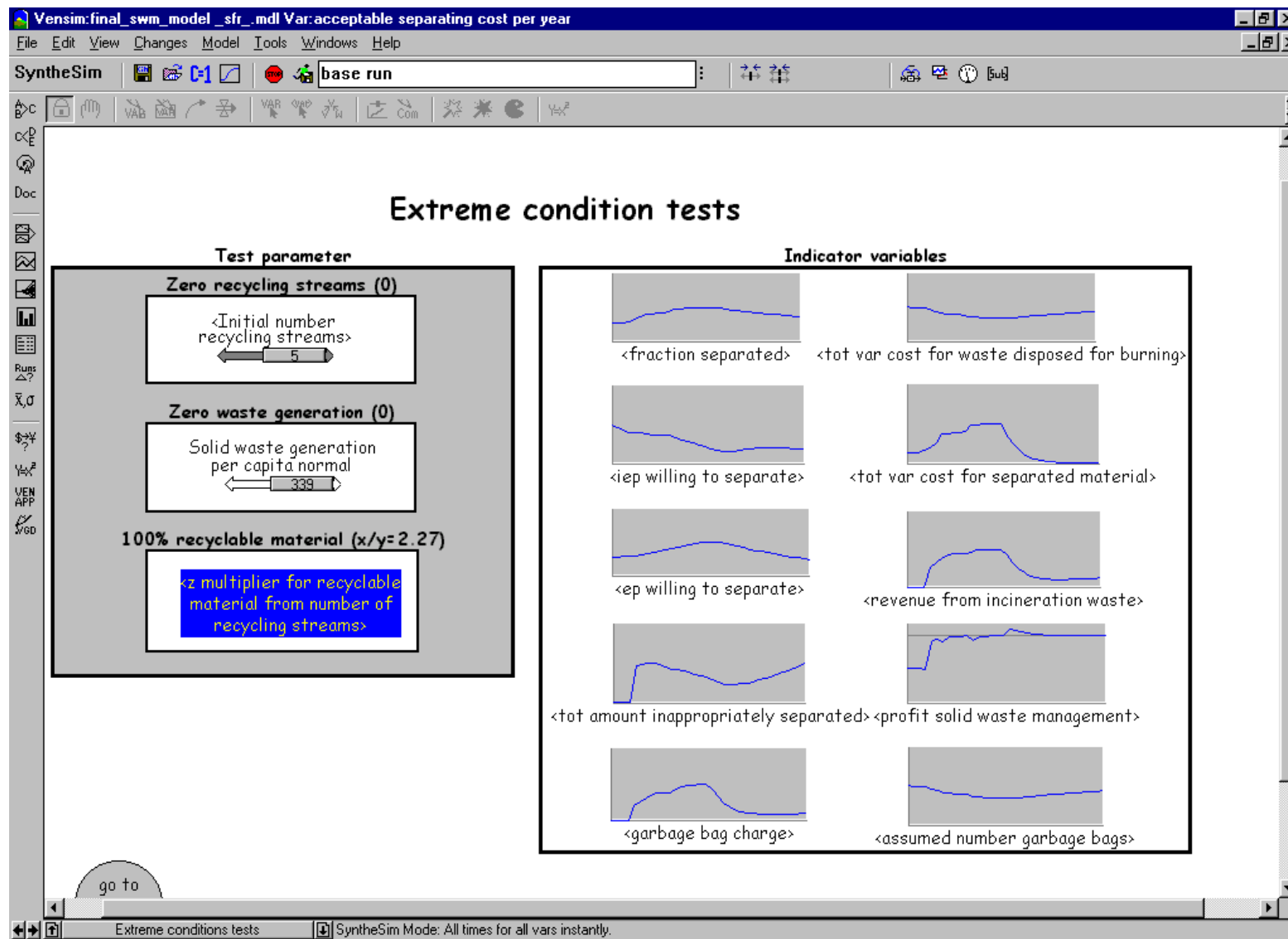
View 04 "Extreme condition tests"

View 05 "Sensitivity analysis"

View 1 "Flows of people"
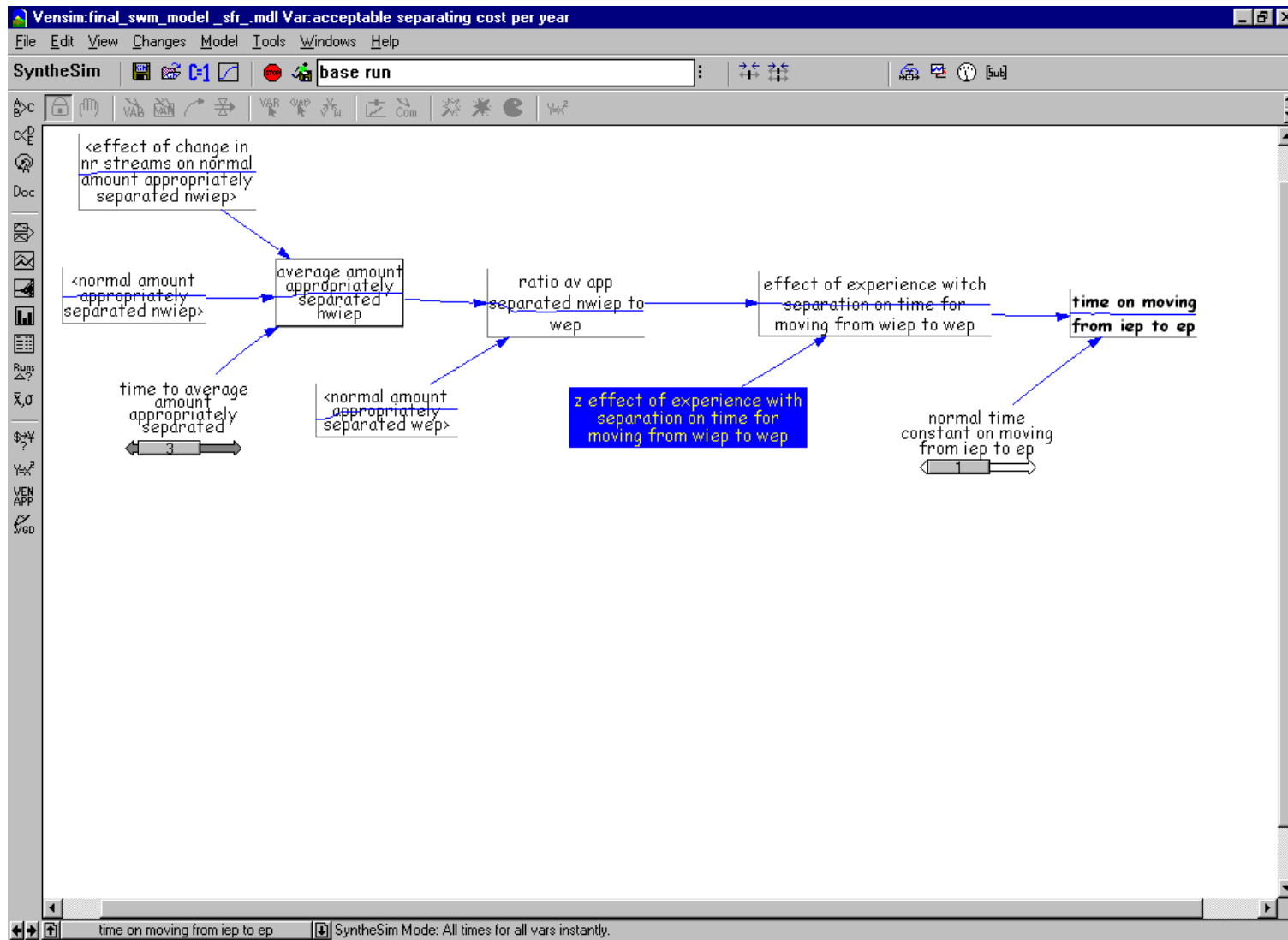
View 11 "Time on moving from iep to ep"
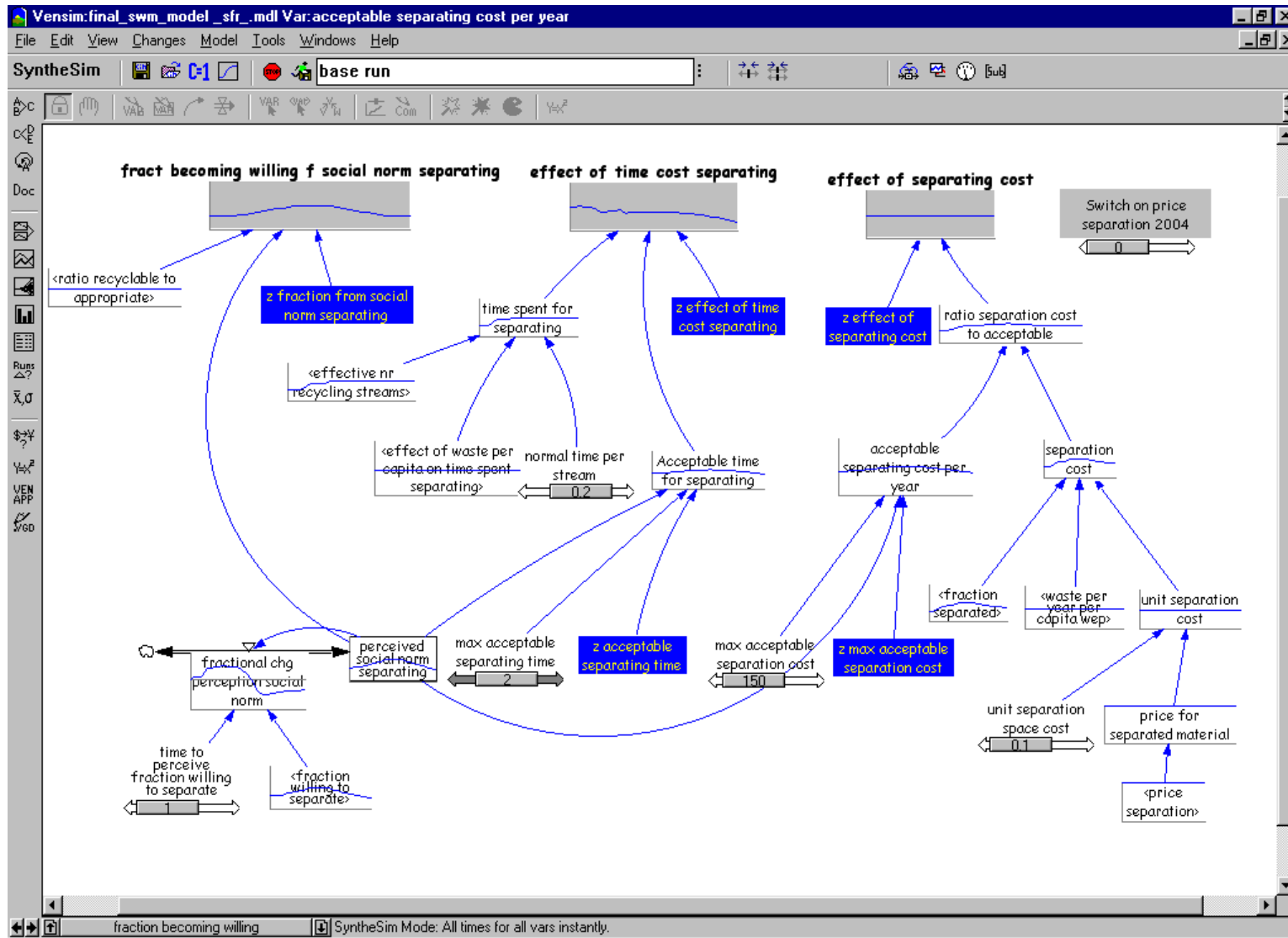
View 2 "Fraction becoming willing"
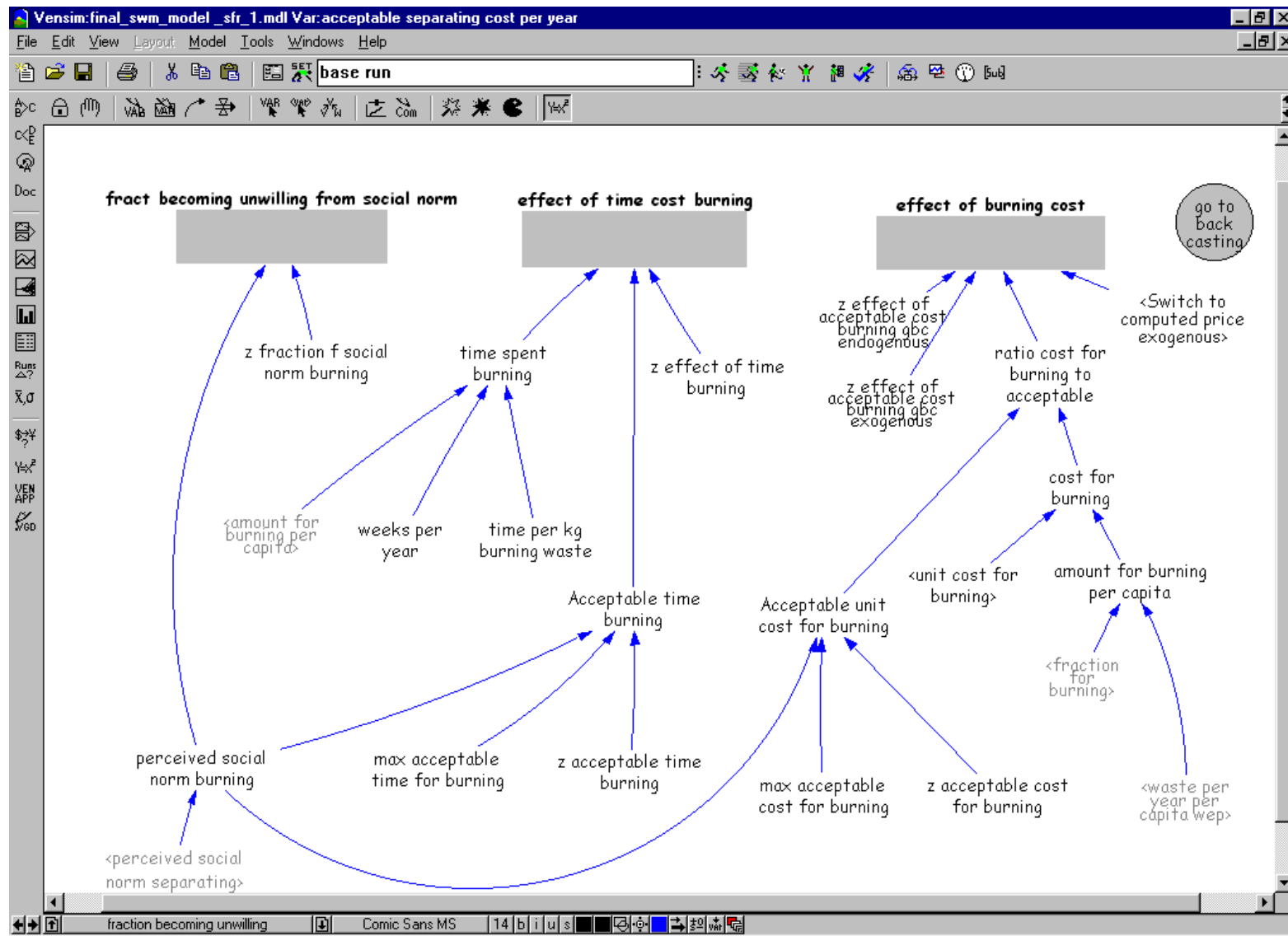
View 3 "Fraction becoming unwilling"

View 31 "Pool for effects on flow people"
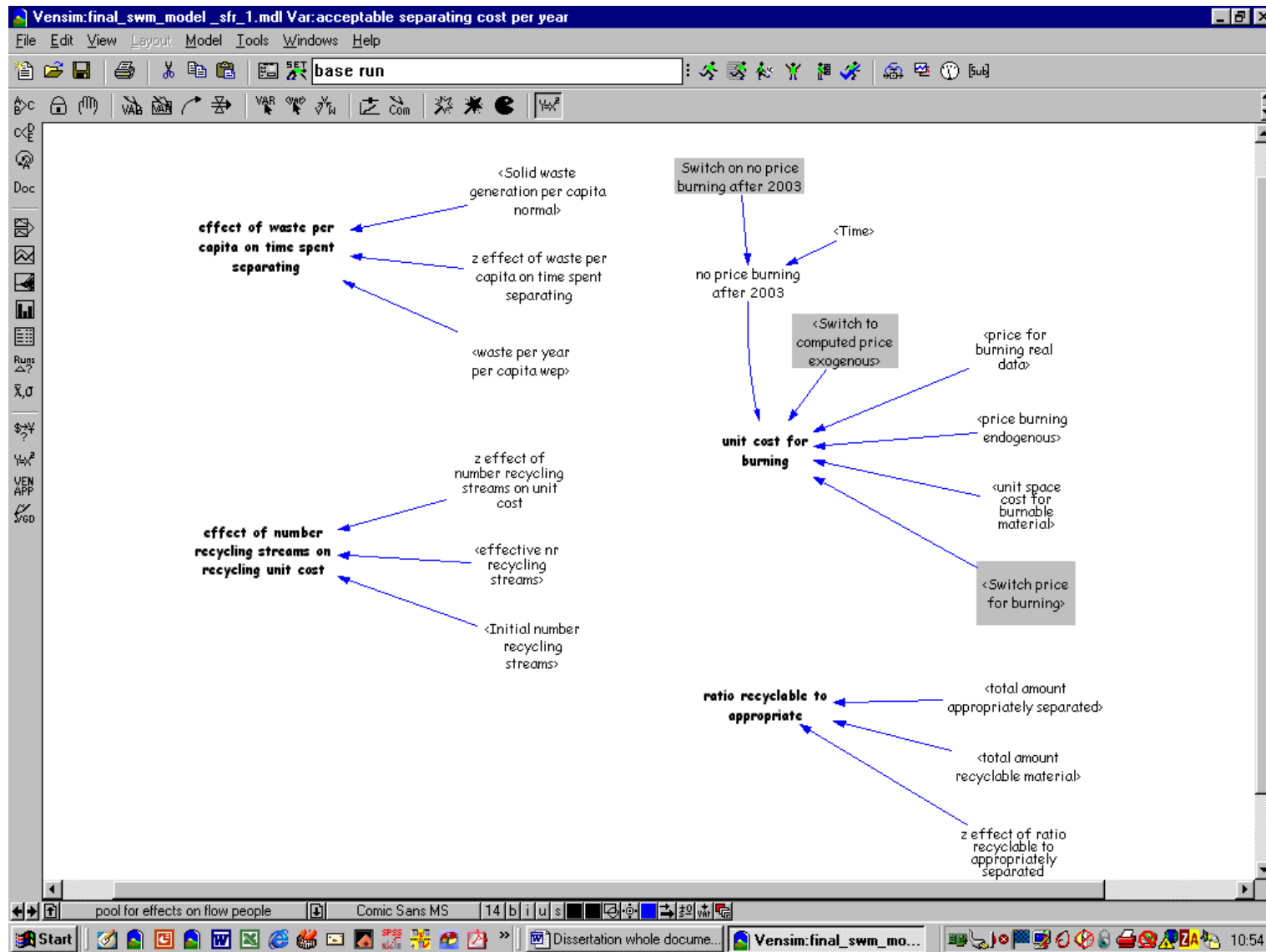
View 4 "separation behavior wep"
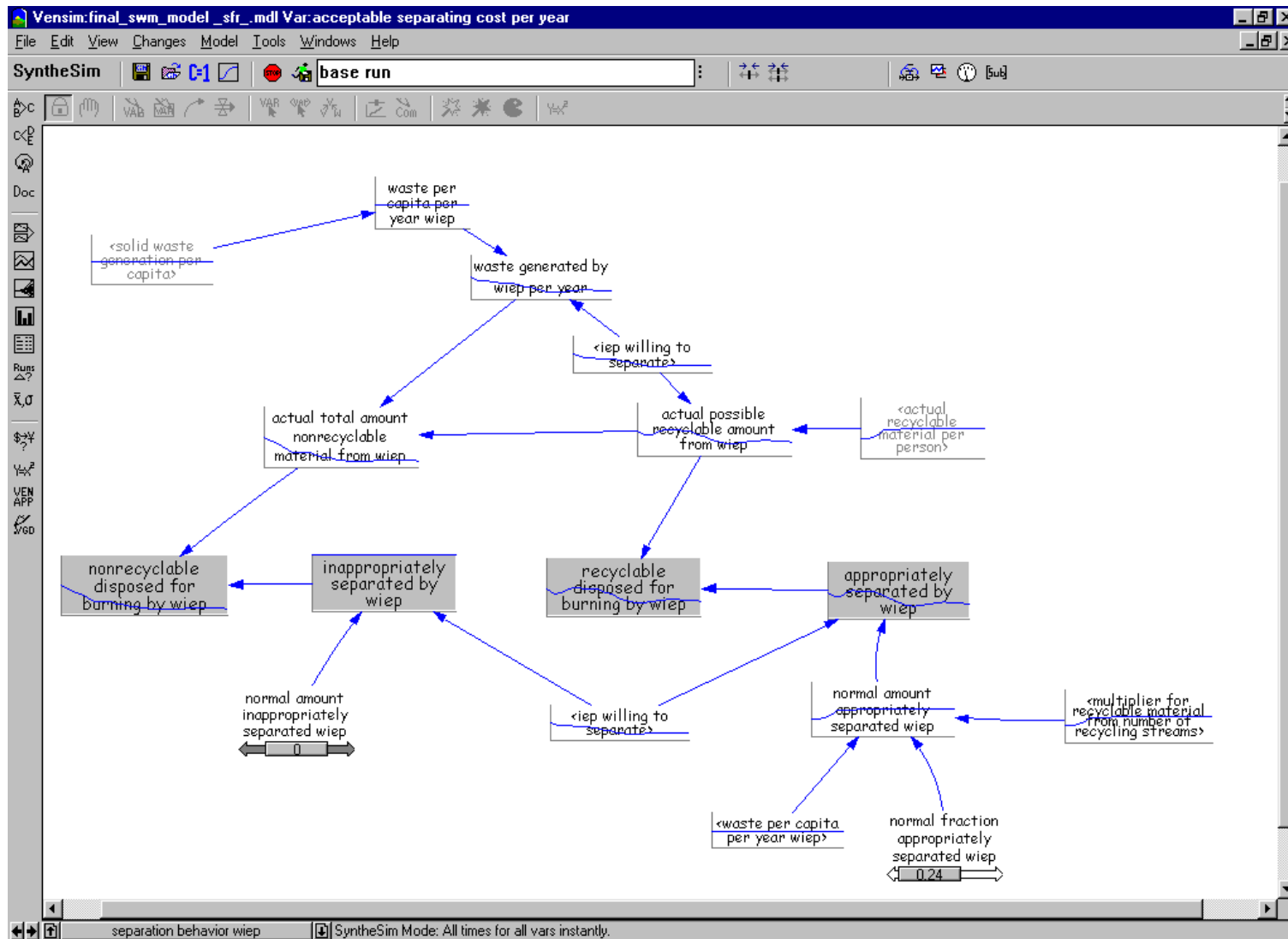
View 5 "Separation behavior wiep"
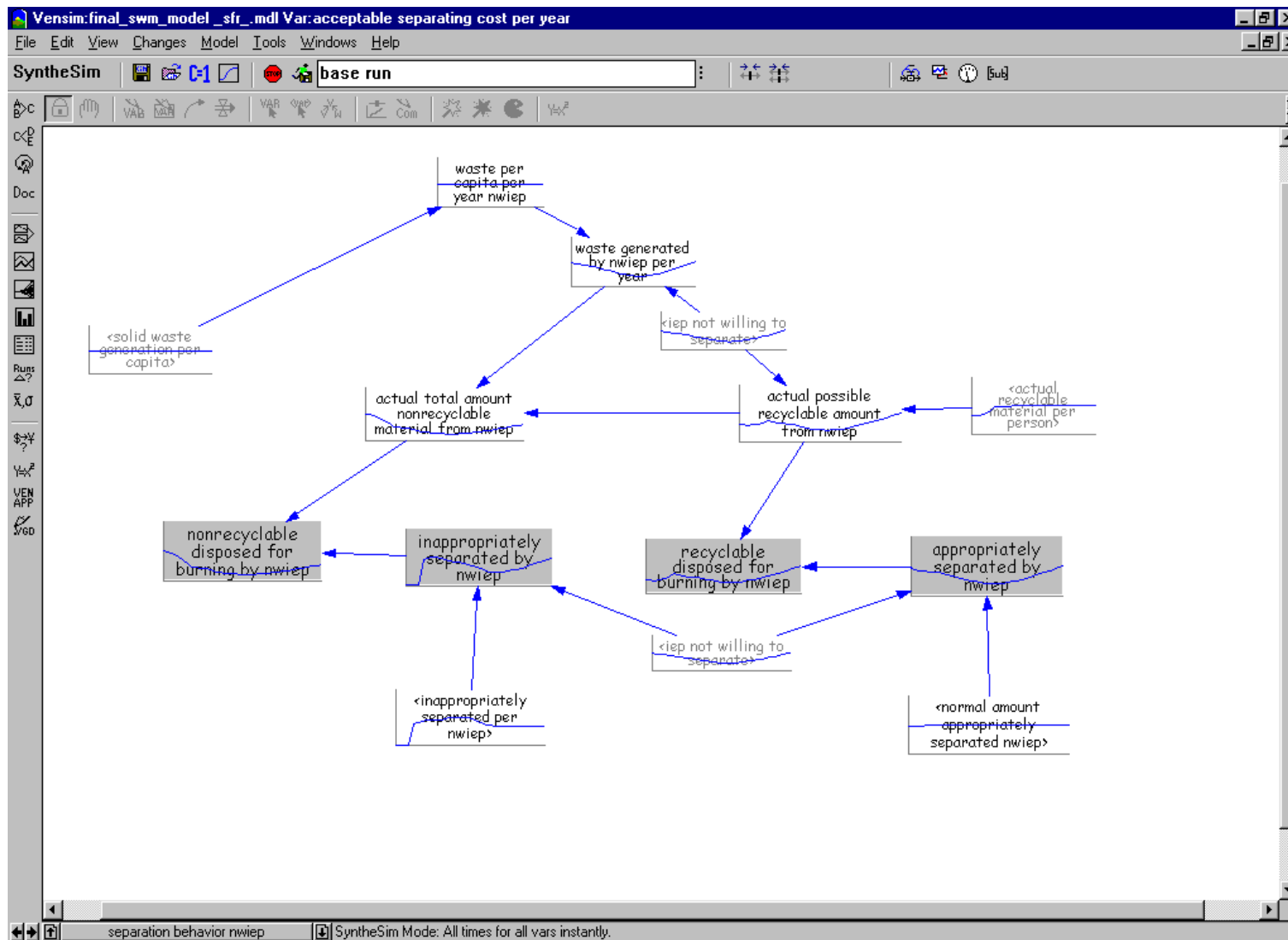
View 6 "Separation behavior nwiep"
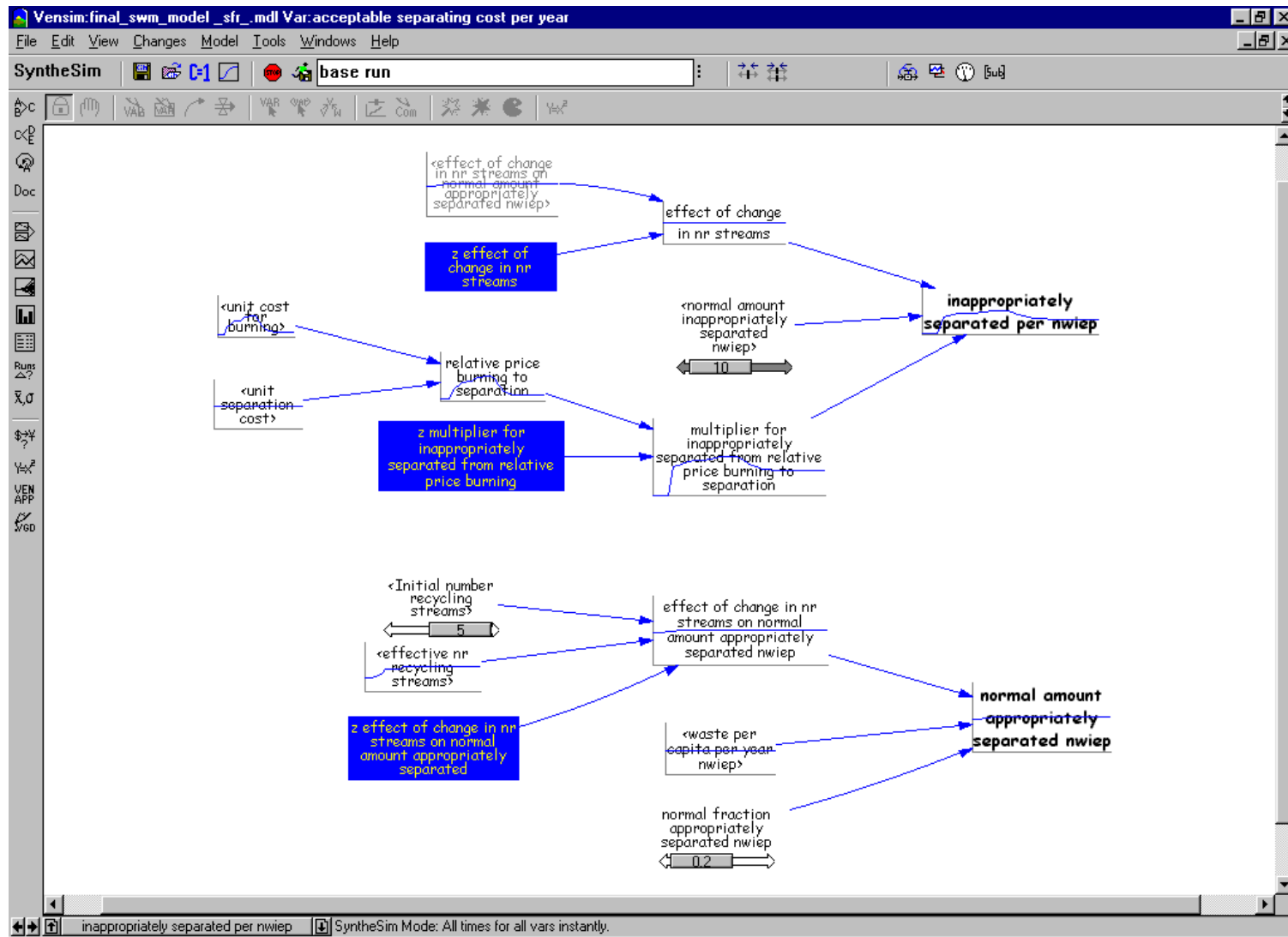
View 61 "Inappropriately separated per nwiep"
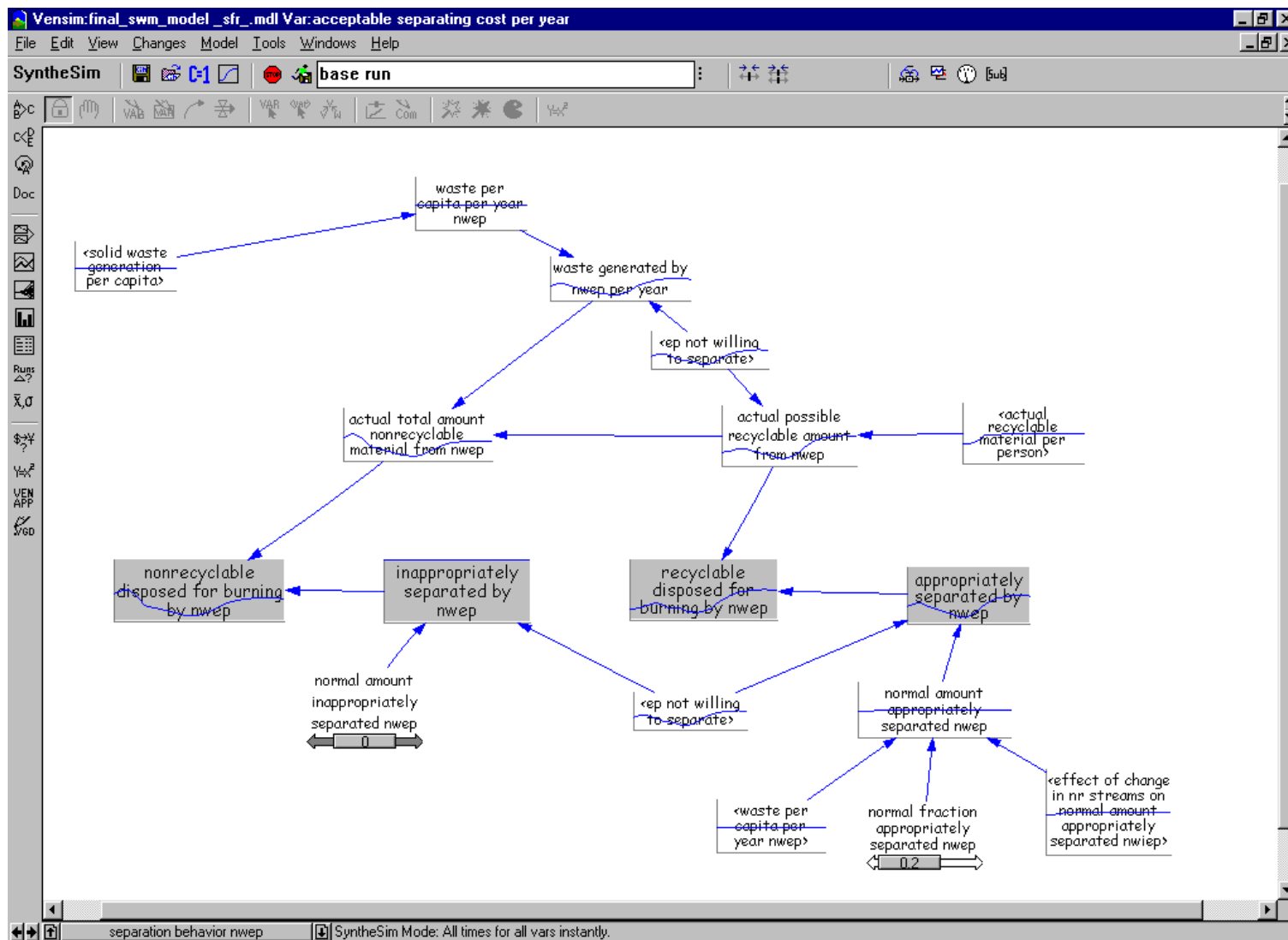
View 7 "Separation behavior nwep"
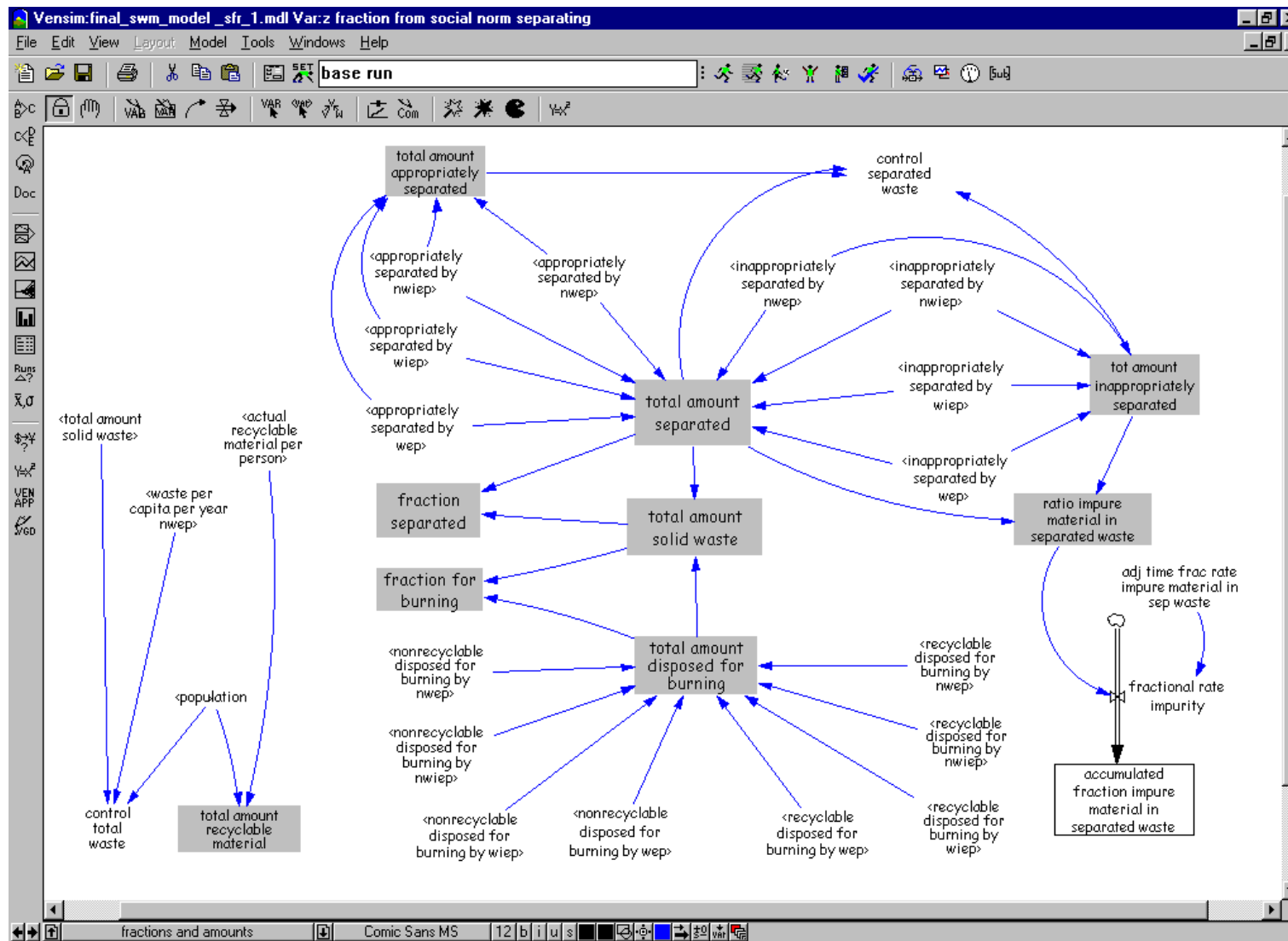
View 8 "Fractions and amounts"
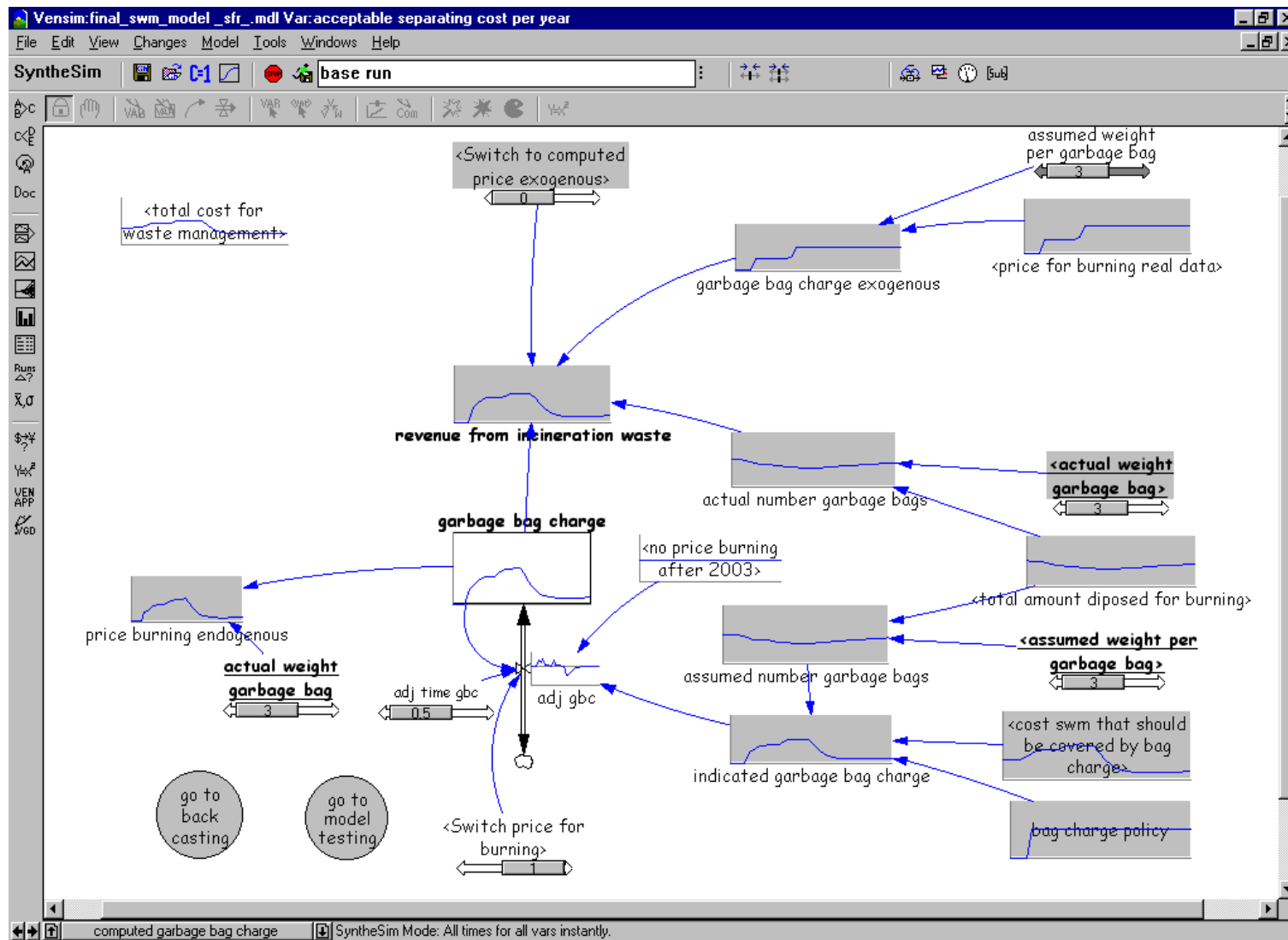
View 9 "Computed garbage bag charge"
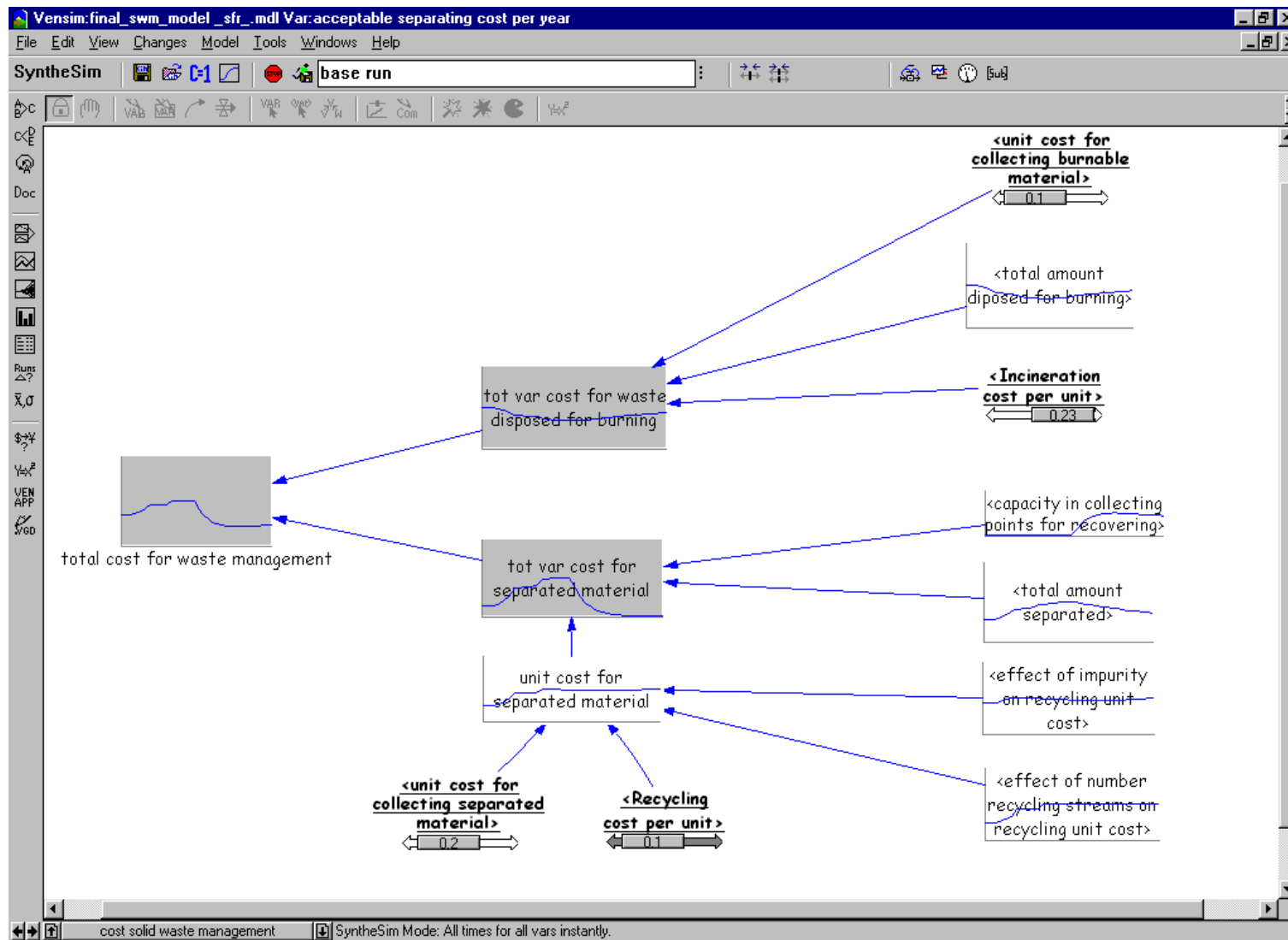
View 91 "Cost solid waste management"
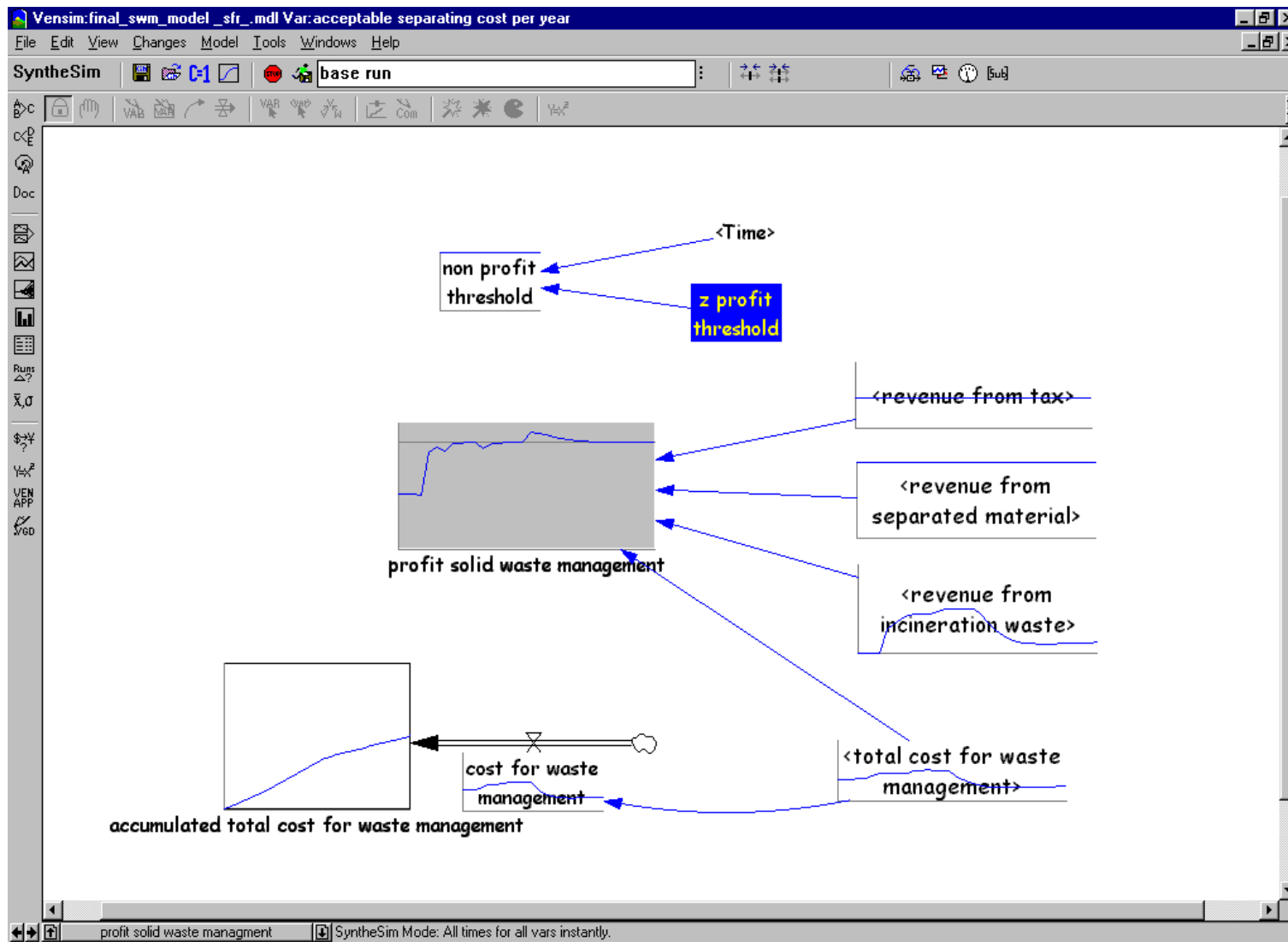
View 911 "Profit solid waste management"
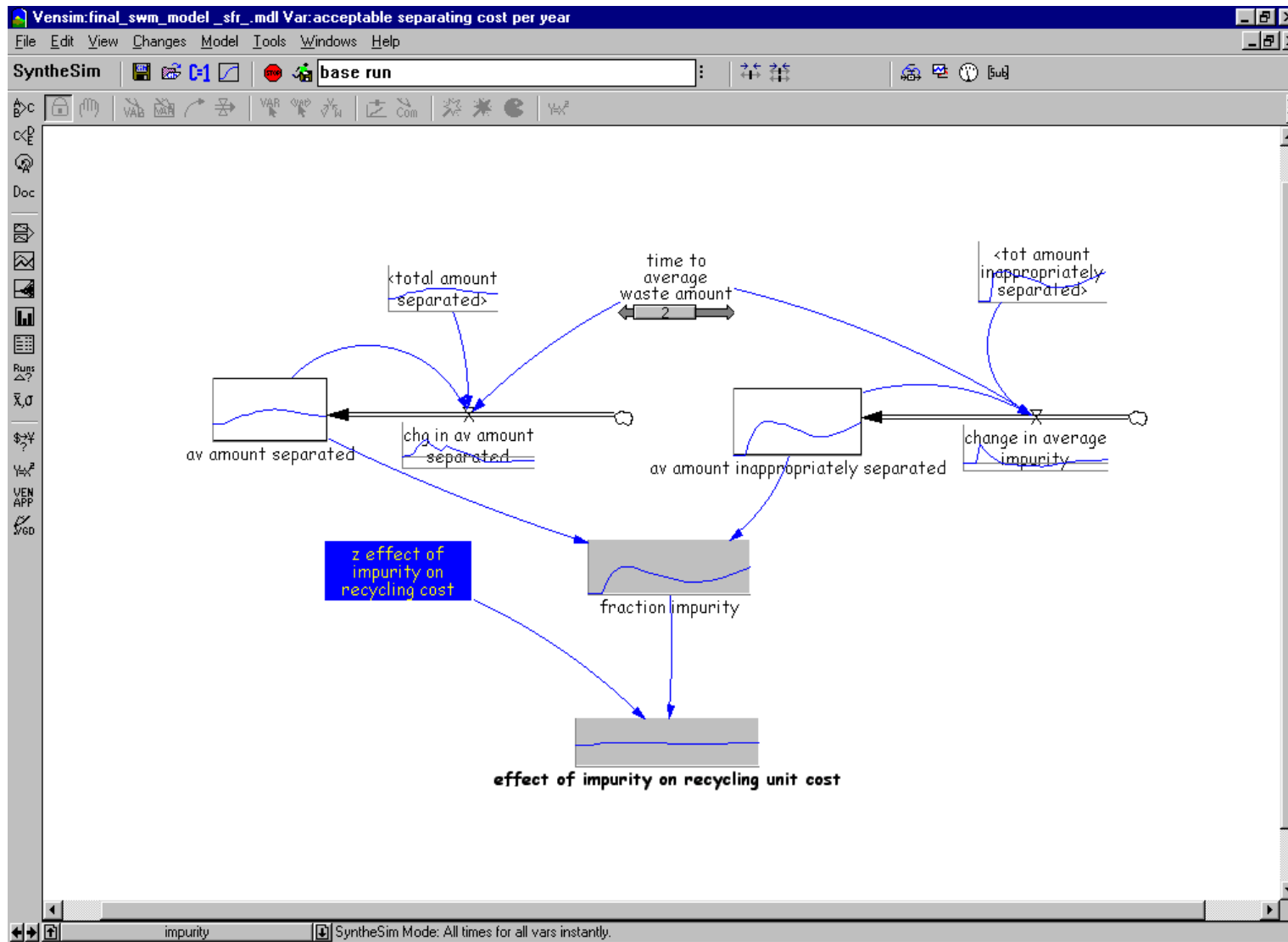
View 92 "Impurity"
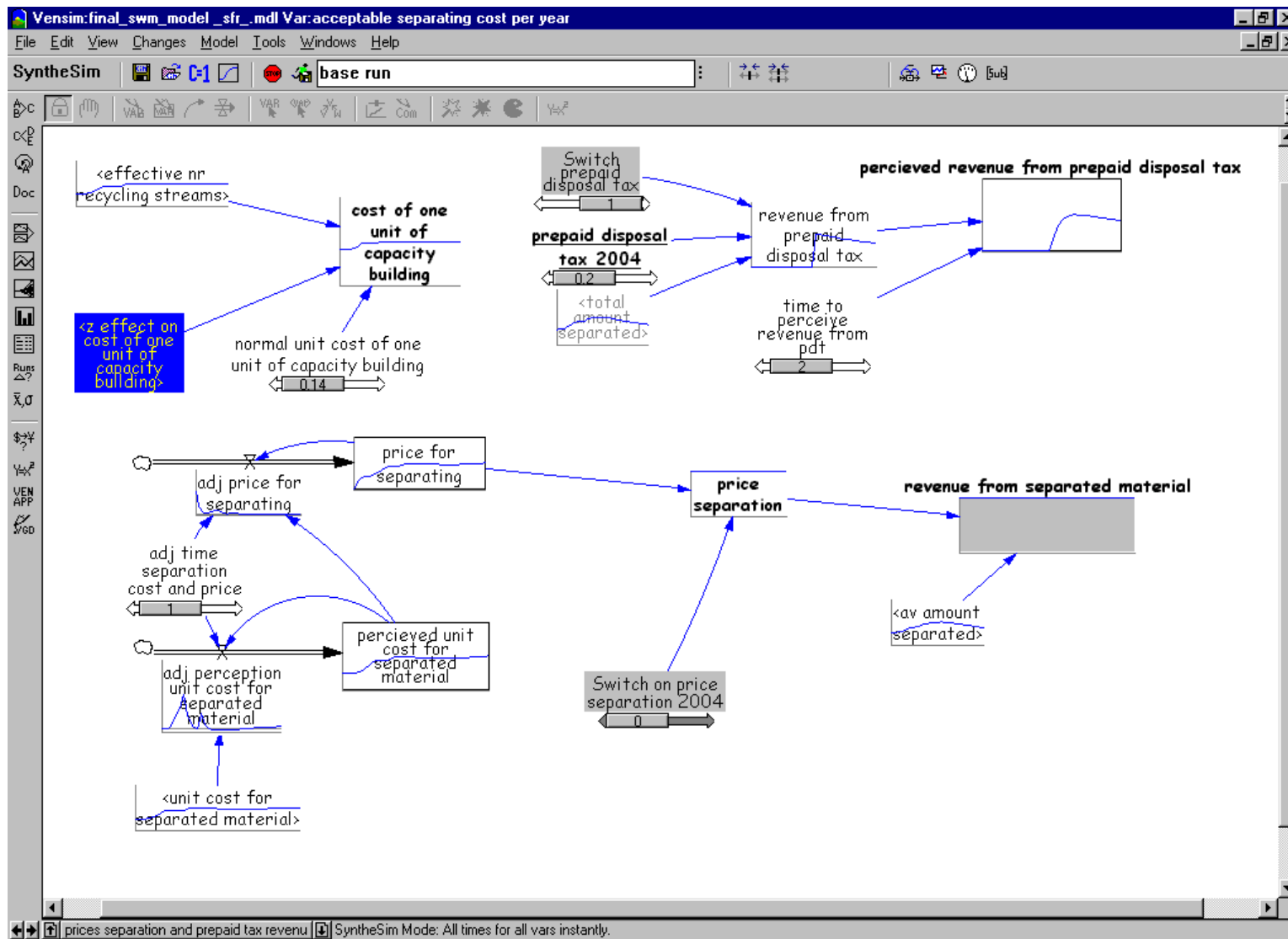
View 93 "Prices separation and prepaid tax revenue"
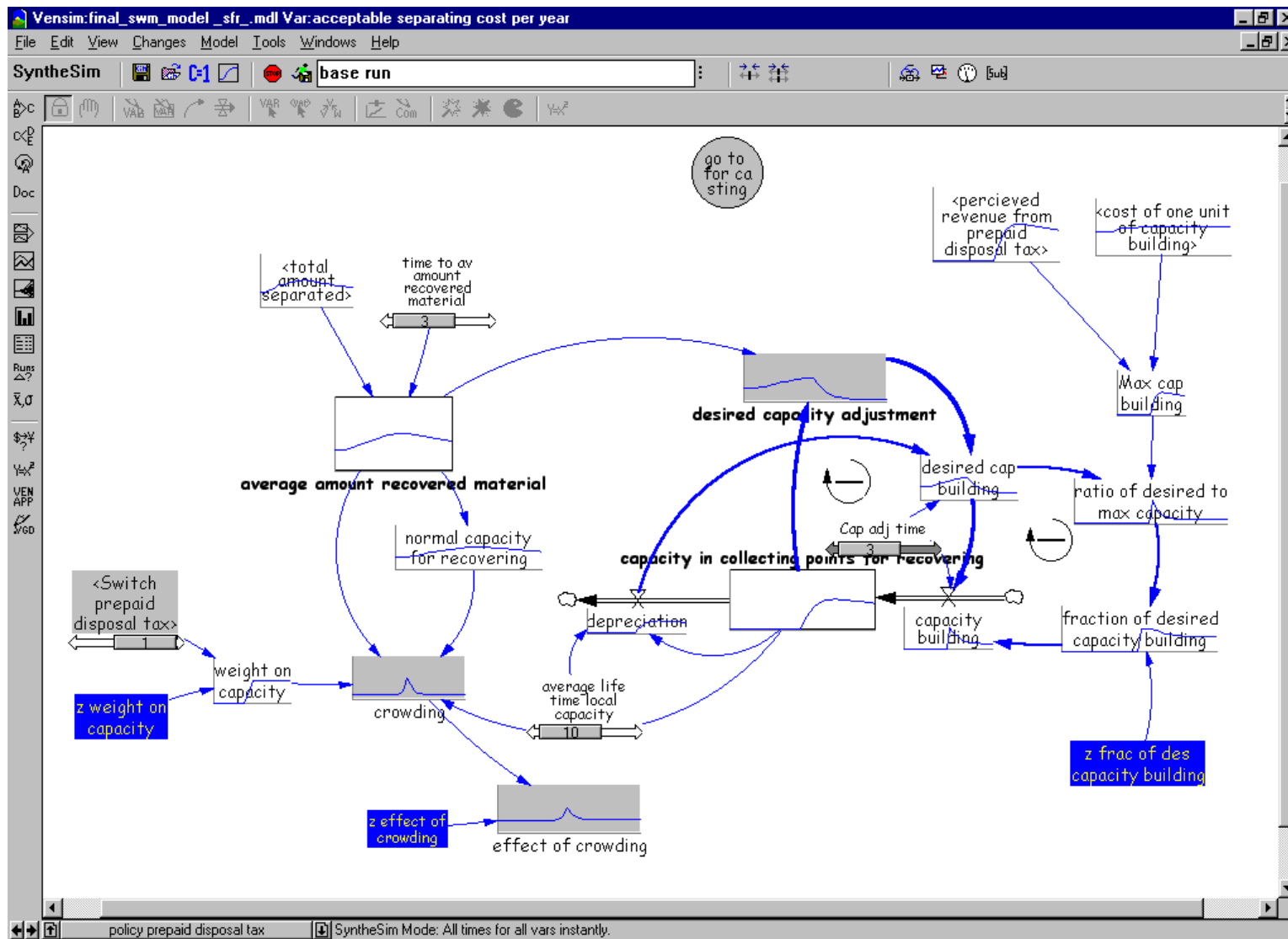
View 94 "Policy prepaid disposal tax"
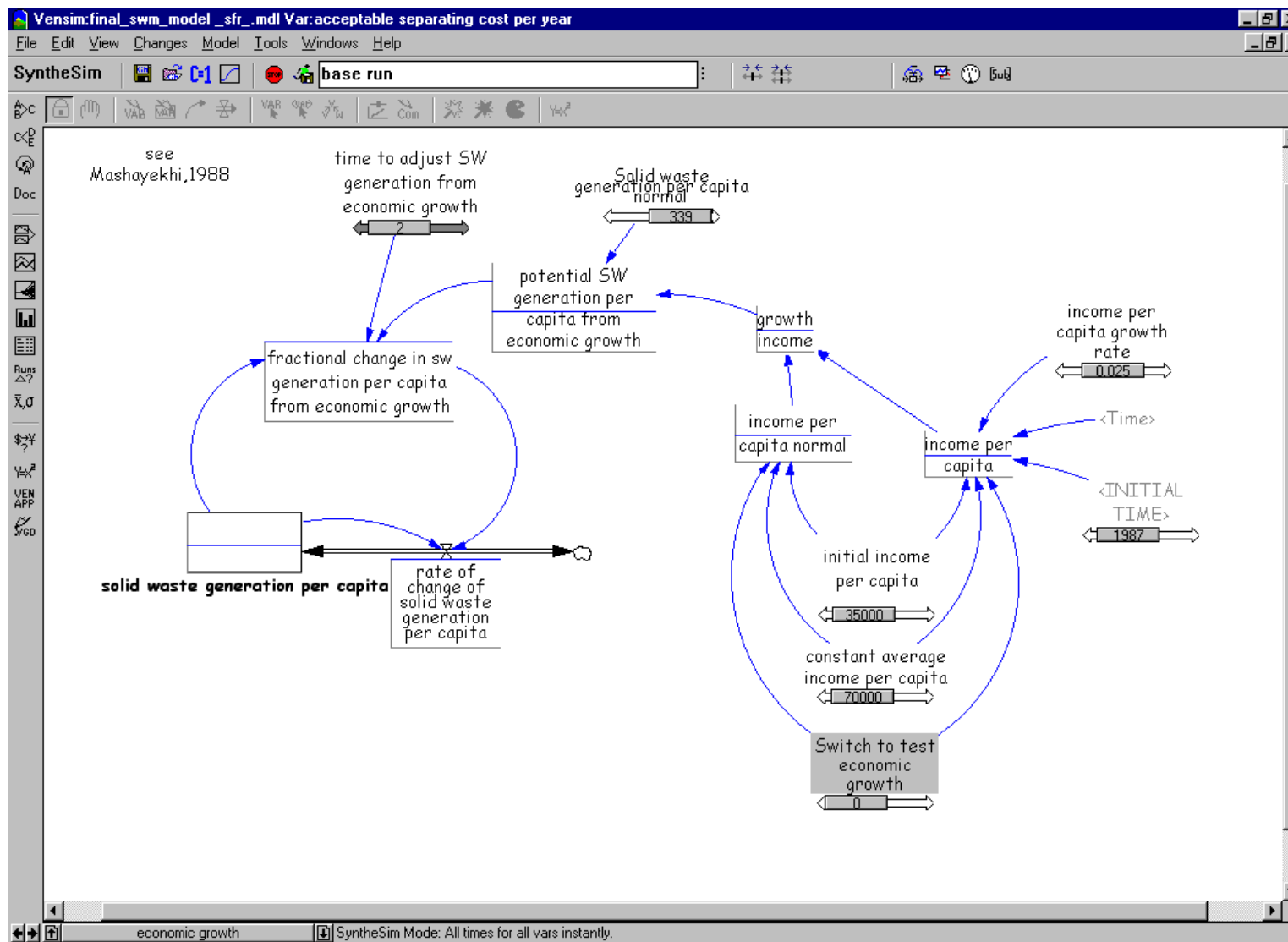
View 95 "Economic growth"
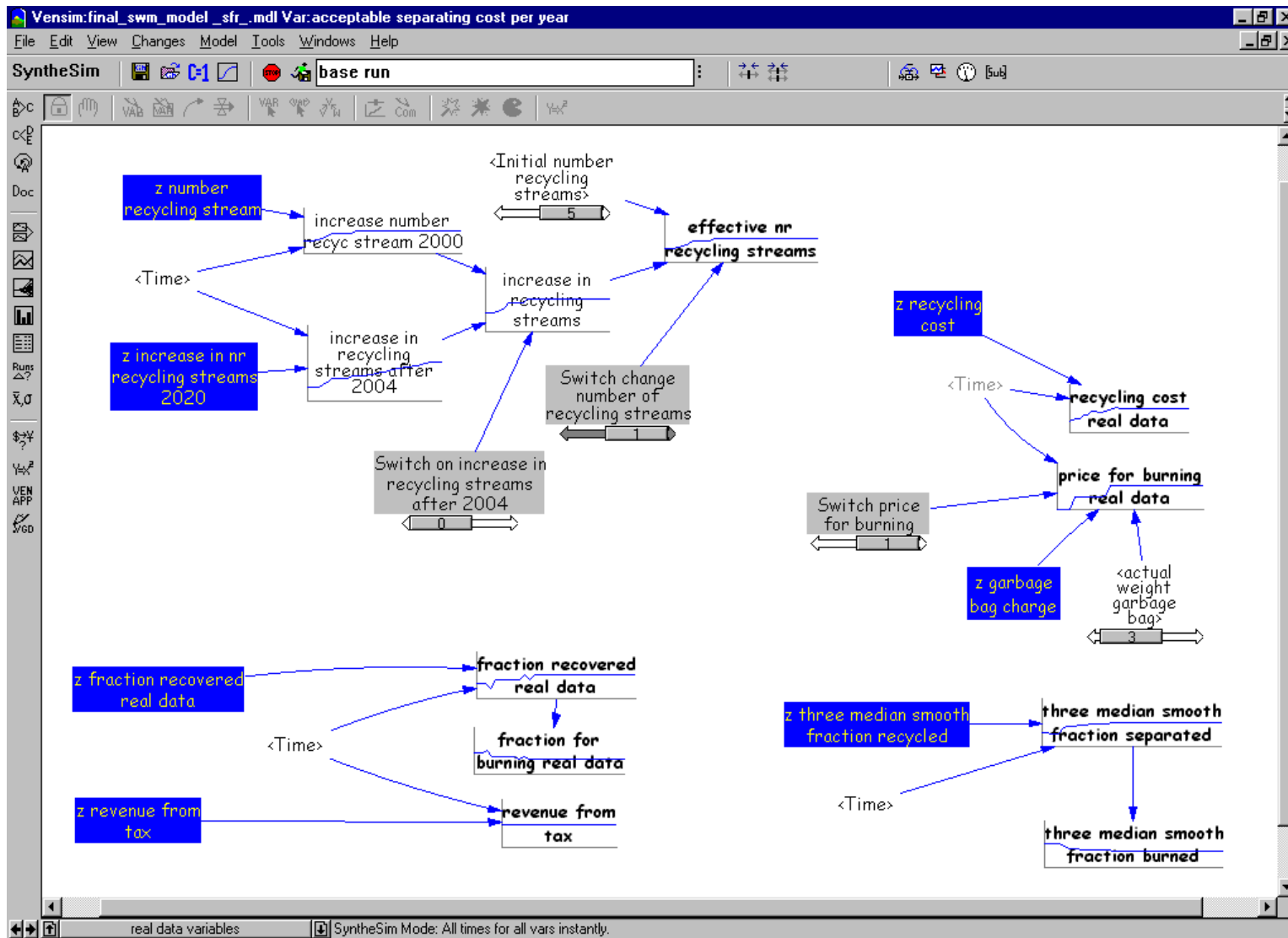
View 96 "Real data variables"

A2 Model structure and equations

****
."1 Flows of people"
****

(007)   average time to forget = 5
    Units: year

(008)   ep getting disappointed =
       wep that could become disappointed*fraction becoming unwilling
    Units: people/year

(009)   ep getting remotivated=
       ep not willing to separate*fraction becoming willing
    Units: people/year

(010)   fraction becoming unwilling=
       fract becoming unwilling from social norm*effect of time cost burning*effect of burning cost* effect of crowding
    Units: Dmnl/year

(011)   fraction becoming willing=
       (fract becoming willing f social norm separating*effect of time cost separating*effect of separating cost)
    Units: Dmnl/year

(012)   iep getting motivated=
       uwp that could become willing*fraction becoming willing
    Units: people/year

(013)   initial value nwep = 1500
    Units: people

(014)   initial value nwp = 5730
    Units: people

(015)   initial value wiep = 663
    Units: people

(016)   min number uw to separate = 1100
    Units: people

(017)   min number w to separate = 1100
    Units: people

(018)   nwep losing experience=
       ep not willing to separate/average time to forget
    Units: people/year

(019)   people willing to separate=
       ep willing to separate+iep willing to separate
    Units: people

(020)   uep getting disappointed=
       iep willing to separate*fraction becoming unwilling
    Units: people/year

(021)   uwp that could become willing=
       MAX(0,(iep not willing to separate-min number uw to seperate))
    Units: people

(022)   wep that could become disappointed=
        MAX(0,(ep willing to separate-min number w to separate))
        Units: people

(023)   wiep getting experienced=
        iep willing to separate*time on moving from iep to ep
        Units: people/year

****
  ."11 time on moving from iep to ep"
****

(025)   average amount appropriately separated nwiep=
                SMOOTH(normal amount appropriately separated nwiep*effect of change in nr streams on normal amount
                appropriately separated nwiep , time to average amount appropriately separated)
        Units: kg/(year*person)

(026)   effect of experience witch separation on time for moving from wiep to wep=
                z effect of experience with separation on time for moving from wiep to wep(ratio av app separated nwiep to
                wep)
        Units: Dmnl

(027)   normal time constant on moving from iep to ep = 1
        Units: Dmnl/year [1,6,1]

(028)   ratio av app separated nwiep to wep=
        zidz (average amount appropriately separated nwiep,normal amount appropriately separated wep)
        Units: Dmnl

(029)   time on moving from iep to ep=
                normal time constant on moving from iep to ep*effect of experience witch separation on time for moving from
                wiep to wep
        Units: Dmnl/years

(030)   time to average amount appropriately separated = 3
        Units: year

(031)   z effect of experience with separation on time for moving from wiep to wep(
        [(0,0)-(1,1)],(0,0),(0.1,0.35),(0.25,0.7),(0.4,0.85),(0.7,0.95),(1,1))
        Units: Dmnl

****
  ."2 Fraction becoming willing"
****

(033)   acceptable separating cost per year=
        z max acceptable separation cost(perceived social norm separating)*max acceptable separation cost
        Units: CHF/(year*person)

(034)   Acceptable time for separating=
        z acceptable separating time(perceived social norm separating)*max acceptable separating time
        Units: hours/week

(035)   effect of separating cost=
        z effect of separating cost(ratio separation cost to acceptable)
        Units: Dmnl

(036)   effect of time cost separating=
        z effect of time cost separating(time spent for separating/Acceptable time for separating)
        Units: Dmnl

(037)   fract becoming willing f social norm separating=
         z fraction from social norm separating(perceived social norm separating)*ratio recyclable to appropriate
       Units: Dmnl/year

(038)   fraction willing to separate=
         people willing to separate/population
       Units: Dmnl

(039)   fractional chg perception social norm=
         ((fraction willing to separate-perceived social norm separating)/time to perceive fraction willing to separate)
       Units: Dmnl/year

(040)   max acceptable separating time = 2
       Units: hours/week [0.8,3,0.1]

(041)   max acceptable separation cost = 150
       Units: CHF/(years*person)

(042)   normal time per stream = 0.2
       Units: hours/(week*streams) [0,0.3,0.01]

(043)   price for separated material=
         price separation
       Units: CHF/kg

(044)   ratio separation cost to acceptable=
         separation cost/acceptable separating cost per year
       Units: Dmnl

(045)   separation cost=
         unit separation cost*(fraction separated*waste per year per capita wep)
       Units: CHF/year/person

(046)   time spent for separating=
         effective nr recycling streams * normal time per stream * effect of waste per capita on time spent separating
       Units: hours/week

(047)   time to perceive fraction willing to separate = 1
       Units: year

(048)   unit separation space cost = 0.1
       Units: CHF/kg

(049)   z acceptable separating time(
         [(0,0)-(1,1)],(0,0),(0.0917431,0.122807),(0.183486,0.328947),(0.284404,0.587719),(0.357798,0.692982),
             (0.422018,0.763158),(0.538226,0.864035),(0.669725,0.942982),(0.83792,0.991228),(1,1))
       Units: Dmnl

(050)   z effect of separating cost(
         [(0,0)-(5,1.4)],(0,1.4),(0.2,1.4),(0.366972,1.35702),(0.458716,1.28333),(0.932722,0.35614),(1.16208,
             0.166667), (1.57492,0.0701754),(2.49235,0),(5,0))
       Units: Dmnl

(051)   z effect of time cost separating(
         [(0,0)-(2,2)],(0,1.5),(0.6,1.5),(0.782875,1.41228),(0.868502,1.27193),(1,1),(1.3,0.3),(1.45,0.13),
             (1.7,0.04),(1.9,0),(2,0))
       Units: Dmnl

(052)   z fraction from social norm separating(
         [(0,0.1)-(1,0.2)],(0,0.1),(0.45,0.1),(0.5,0.105),(0.56,0.125),(0.64,0.15),(0.7,0.17),(0.8,0.19),

(0.88,0.2),(1,0.2))
Units: Dmnl/year

(053)   z max acceptable separation cost(
[(0,0)-(1,1)],(0,0.00438596),(0.0795107,0.267544),(0.180428,0.495614),(0.281346,0.644737),
(0.394495,0.758772),(0.525994,0.855263),(0.654434,0.934211),(0.807339,0.982456),(0.990826,1))
Units: Dmnl

****
.**"3 Fraction becoming unwilling"**
****

(055)   Acceptable time burning=
z acceptable time burning(perceived fraction social norm burning)*max acceptable time for burning
Units: hours/(person*week)

(056)   Acceptable unit cost for burning=
z acceptable cost for burning(perceived fraction social norm burning)*max acceptable cost for burning
Units: CHF/year/person

(057)   amount for burning per capita=
fraction for burning*waste per year per capita wep
Units: kg/(year*person)

(058)   cost for burning=
unit cost for burning*amount for burning per capita
Units: CHF/year/person

(059)   effect of burning cost=
z effect of acceptable cost burning gbc endogenous(ratio cost for burning to acceptable)*(1-Switch to
computed price exogenous)+z effect of acceptable cost burning gbc exogenous(ratio cost for burning to
acceptable)*Switch to computed price exogenous
Units: Dmnl

(060)   effect of time cost burning=
z effect of time burning(time spent burning/Acceptable time burning)
Units: Dmnl

(061)   fract becoming unwilling from social norm=
z fraction f social norm burning(perceived fraction social norm burning)
Units: Dmnl/year

(062)   max acceptable cost for burning = 180
Units: CHF/year/person

(063)   max acceptable time for burning = 1
Units: hours/(week*person)

(064)   perceived social norm separating= INTEG (fractional chg perception social norm, fraction willing to separate)
Units: Dmnl

(065)   perceived fraction social norm burning=
1-perceived social norm separating
Units: Dmnl

(066)   ratio cost for burning to acceptable=
cost for burning/Acceptable unit cost for burning
Units: Dmnl

(067)   time per kg burning waste=
0.1

Units: hours/kg

(068)   time spent burning=
         (amount for burning per capita/weeks per year)*time per kg burning waste
         Units: hours/(person*week)

(069)   weeks per year=
         52
         Units: weeks/year

(070)   z acceptable cost for burning(
         [(0,0)-(1,1)],(0.0030581,0.394737),(0.088685,0.508772),(0.211009,0.666667),(0.379205,0.811404),
                 (0.587156,0.907895),(0.776758,0.973684),(1,1))
         Units: Dmnl

(071)   z acceptable time burning(
         [(0,0)-(1,1)],(0,0),(0.0519878,0.263158),(0.165138,0.635965),(0.357798,0.890351),(0.584098,0.964912),
                 (1,1))
         Units: Dmnl

(072)   z effect of acceptable cost burning gbc endogenous(
         [(0,0)-(5,1)],(0,1),(0.7,0.31),(0.8,0.2),(1,0.1),(1.2,0.06),(1.5,0.03),(2.5,0),(5,0))
         Units: Dmnl

(073)   z effect of acceptable cost burning gbc exogenous(
         [(0,0)-(5,1)],(0,1),(0.5,0.32),(0.65,0.2),(0.95,0.1),(1.2,0.06),(1.5,0.03),(2.5,0),(5,0))
         Units: Dmnl

(074)   z effect of time burning(
         [(0,0)-(2,1.2)],(0,1.1),(0.2,1.1),(0.7,1.05),(1,1),(1.15,0.85),(1.4,0.1),(1.6,0),(2,0))
         Units: Dmnl

(075)   z fraction f social norm burning(
         [(0,0.1)-(1,0.4)],(0,0.19),(0.1,0.19),(0.3,0.2),(0.45,0.22),(0.55,0.23),(1,0.23))
         Units: Dmnl/year

****
 ."31 Pool for effects on flow people"
****

(077)   effect of waste per capita on time spent separating=
                  z effect of waste per capita on time spent separating(zidz(waste per year per capita wep,Solid waste
         generation per capita normal))
         Units: Dmnl

(078)   ratio recyclable to appropriate=
         z effect or ratio recyclable to appropriately separated(zidz(total amount recyclable material
                 ,total amount appropriately separated))
         Units: Dmnl

(079)   Switch on no price burning after 2003 = 0
         Units: Dmnl [0,1,1]

(080)   unit space cost for burnable material =   0.05
         Units: CHF/kg

(081)   z effect of number recycling streams on unit cost(
         [(0,0)-(4,10)],(0.03,10),(0.25,5),(0.36,3.5),(0.5,2.4),(0.7,1.5),(1,1),(1.5,0.6),(2.5,0.2),(3 ,0.09),(4,0))
         Units: Dmnl

(082)   z effect of waste per capita on time spent separating(

[(0,0)-(4,1.2)],(0,0),(0.3,0.49),(0.5,0.73),(0.7,0.9),(1,1),(1.4,1.1),(2.2,1.16),(2.7,1.18),(4,1.2))
Units: Dmnl

(083)   z effect of ratio recyclable to appropriately separated(
[(0,0)-(2,1)],(0,0),(0.07,0.03),(0.2,0.9),(0.26,0.97),(0.33,1),(2,1))
Units: Dmnl

****
  ."4 Separation behavior wep"
****

(085)   actual possible recyclable amount from wep=
actual recyclable material per person*ep willing to separate
Units: kg/year

(086)   actual total amount nonrecyclable material from wep=
waste generated by wep per year-actual possible recyclable amount from wep
Units: kg/year

(087)   ep willing to separate= INTEG (wiep getting experienced+ep getting remotivated-ep getting disappointed,
(population - initial value nwp-initial value wiep))
Units: people

(088)   normal amount appropriately separated wep=
waste per year per capita wep*normal fraction appropriately separated wep*multiplier for recyclable material
from number of recycling streams
Units: kg/(people*year)

(089)   normal amount inappropriately separated wep =   0
Units: kg/(people*year)

(090)   normal fraction appropriately separated wep = 0.38
Units: Dmnl

(091)   normal fraction recyclable = 0.44
Units: Dmnl [0.44,1]

(092)   waste generated by wep per year=
ep willing to separate*waste per year per capita wep
Units: kg/year

(093)   waste per year per capita wep=
solid waste generation per capita
Units: kg/(person*year)

(094)   z multiplier for recyclable material from number of recycling streams(
[(0,0)-(4,2)],(0,0),(0.75,0.75),(1.2,1.2),(1.6,1.45),(1.9,1.6),(2.29969,1.7),(2.9,1.75),(4,1.85))
Units: Dmnl

****
  ."5 separation behavior wiep"
****

(096)   actual possible recyclable amount from wiep=
actual recyclable material per person*iep willing to separate
Units: kg/year

(097)   actual total amount nonrecyclable material from wiep=
waste generated by wiep per year-actual possible recyclable amount from wiep
Units: kg/year

(098)   iep willing to separate= INTEG (iep getting motivated-uep getting disappointed-wiep getting experienced,   initial
value wiep)
    Units: people

(099)   multiplier for recyclable material from number of recycling streams=
       z multiplier for recyclable material from number of recycling streams(zidz(effective nr recycling streams,
Initial number recycling streams))
    Units: Dmnl

(100)   normal amount appropriately separated wiep=
            normal fraction appropriately separated wiep*waste per capita per year wiep*multiplier for recyclable material
            from number of recycling streams
    Units: kg/(people*year)

(101)   normal amount inappropriately separated wiep = 0
    Units: kg/(people*year)

(102)   normal fraction appropriately separated wiep = 0.24
    Units: Dmnl

(103)   waste generated by wiep per year =
       waste per capita per year wiep*iep willing to separate
    Units: kg/year

(104)   waste per capita per year wiep=
       solid waste generation per capita
    Units: kg/(year*people)

****
 ."6 Separation behavior nwiep"
****

(106)   actual possible recyclable amount from nwiep=
       actual recyclable material per person*iep not willing to separate
    Units: kg/year

(107)   actual total amount nonrecyclable material from nwiep=
       waste generated by nwiep per year-actual possible recyclable amount from nwiep
    Units: kg/year

(108)   iep not willing to separate= INTEG (nwep losing experience+uep getting disappointed-iep getting motivated,
       initial value nwp-initial value nwep)
    Units: people

(109)   waste generated by nwiep per year=
       iep not willing to separate*waste per capita per year nwiep
    Units: kg/year

****
 ."61 Inappropriately separated per nwiep"
****

(111)   effect of change in nr streams=
            z effect of change in nr streams(effect of change in nr streams on normal amount appropriately separated
            nwiep)
    Units: Dmnl

(112)   inappropriately separated per nwiep=
            normal amount inappropriately separated nwiep*multiplier for inappropriately separated from relative price
            burning to separation *effect of change in nr streams
    Units: kg/(people*year)

(113)   multiplier for inappropriately separated from relative price burning to separation=
         z multiplier for inappropriately separated from relative price burning(relative price burning to separation)
    Units: Dmnl

(114)   normal amount appropriately separated nwiep=
                waste per capita per year nwiep*normal fraction appropriately separated nwiep*effect of change in nr streams
                on normal amount appropriately separated nwiep
    Units: kg/(people*year)

(115)   normal amount inappropriately separated nwiep = 10
    Units: kg/(people*year)

(116)   normal fraction appropriately separated nwiep = 0.2
    Units: Dmnl

(117)   relative price burning to separation=
         unit cost for burning/unit separation cost
    Units: Dmnl

(118)   unit cost for burning=
         ((price for burning real data+unit space cost for burnable material)* (Switch to computed price exogenous)) +
         ((unit space cost for burnable material+price burning endogenous*Switch price for burning)*
         (1-Switch to computed price exogenous))*no price burning after 2003
    Units: CHF/kg

(119)   unit separation cost=
         unit separation space cost+price for separated material
    Units: CHF/kg

(120)   waste per capita per year nwiep=
         solid waste generation per capita
    Units: kg/(year*people)

(121)   z effect of change in nr streams(
         [(0,0)-(5,3)],(0,0),(1,1),(5,2))
    Units: Dmnl

(122)   z effect of change in nr streams on normal amount appropriately separated(
         [(0,0)-(4,1.1)],(0,0),(1,1),(1.16,1.04),(1.45,1.07),(4,1.1))
    Units: Dmnl

(123)   z multiplier for inappropriately separated from relative price burning(
         [(0,0)-(15,10)],(0,0),(0.5,0),(0.7,0.2),(1,1),(10,2),(15,3))
    Units: Dmnl

****
.**"7 Separation behavior nwep"**
****

(125)   actual possible recyclable amount from nwep=
         actual recyclable material per person*ep not willing to separate
    Units: kg/year

(126)   actual total amount nonrecyclable material from nwep=
         waste generated by nwep per year-actual possible recyclable amount from nwep
    Units: kg/year

(127)   effect of change in nr streams on normal amount appropriately separated nwiep=
         z effect of change in nr streams on normal amount appropriately separated(zidz
                (effective nr recycling streams, Initial number recycling streams))

Units: Dmnl

(128) ep not willing to separate= INTEG (
        ep getting disappointed-nwep losing experience-ep getting remotivated, initial value nwep)
    Units: people

(129) normal amount appropriately separated nwep=
        normal fraction appropriately separated nwep*waste per capita per year nwep*effect of change in nr streams
        on normal amount appropriately separated nwiep
    Units: kg/(people*year)

(130) normal amount inappropriately separated nwep = 0
    Units: kg/(people*year)

(131) normal fraction appropriately separated nwep = 0.2
    Units: Dmnl

(132) waste generated by nwep per year = ep not willing to separate*waste per capita per year nwep
    Units: kg/year

****
 ."8 Fractions and amounts"
****

(134) accumulated fraction impure material in separated waste= INTEG (
        fractional rate impurity, 0)
    Units: Dmnl

(135) actual recyclable material per person=
        normal fraction recyclable*waste per year per capita wep*multiplier for recyclable material from number of
        recycling streams
    Units: kg/(people*year)

(136) adj time frac rate impure material in sep waste = 1
    Units: year

(137) appropriately separated by newp=
    normal amount appropriately separated nwep*ep not willing to separate
    Units: kg/year

(138) appropriately separated by nwiep=
    normal amount appropriately separated nwiep*iep not willing to separate
    Units: kg/year

(139) appropriately separated by wep=
    normal amount appropriately separated wep*ep willing to separate
    Units: kg/year

(140) appropriately separated by wiep=
    normal amount appropriately separated wiep*iep willing to separate
    Units: kg/year

(141) control separated waste=
    zidz((total amount appropriately separated+tot amount inappropriately separated), total amount separated)
    Units: Dmnl

(142) control total waste=
    zidz((population*waste per capita per year nwep),total amount solid waste)
    Units: Dmnl

(143) fraction for burning=

zidz(total amount diposed for burning , total amount solid waste)
Units: Dmnl

(144)   fraction separated=
zidz(total amount separated,total amount solid waste)
Units: Dmnl

(145)   fractional rate impurity=
ratio impure material in separated waste/adj time frac rate impure material in sep waste
Units: Dmnl/year

(146)   inappropriately separated by nwep=
normal amount inappropriately separated nwep*ep not willing to separate
Units: kg/year

(147)   inappropriately separated by nwiep=
inappropriately separated per nwiep*iep not willing to separate
Units: kg/year

(148)   inappropriately separated by wep=
normal amount inappropriately separated wep*ep willing to separate
Units: kg/year

(149)   inappropriately separated by wiep=
normal amount inappropriately separated wiep*iep willing to separate
Units: kg/year

(150)   nonrecyclable disposed for burning by nwep=
actual total amount nonrecyclable material from nwep-inappropriately separated by nwep
Units: kg/year

(151)   nonrecyclable disposed for burning by nwiep=
actual total amount nonrecyclable material from nwiep-inappropriately separated by nwiep
Units: kg/year

(152)   nonrecyclable disposed for burning by wep=
actual total amount nonrecyclable material from wep-inappropriately separated by wep
Units: kg/year

(153)   nonrecyclable disposed for burning by wiep=
actual total amount nonrecyclable material from wiep-inappropriately separated by wiep
Units: kg/year

(154)   population = 10705
Units: people

(155)   ratio impure material in separated waste=
zidz(tot amount inappropriately separated , total amount separated)
Units: Dmnl

(156)   recyclable disposed for burning by nwep=
actual possible recyclable amount from nwep-appropriately separated by nwep
Units: kg/year

(157)   recyclable disposed for burning by nwiep=
actual possible recyclable amount from nwiep-appropriately separated by nwiep
Units: kg/year

(158)   recyclable disposed for burning by wep=
actual possible recyclable amount from wep-appropriately separated by wep
Units: kg/year

(159)   recyclable disposed for burning by wiep=
         actual possible recyclable amount from wiep-appropriately separated by wiep
     Units: kg/year

(160)   total amount recyclable material=
         actual recyclable material per person*population
     Units: kg/year

(161)   total amount solid waste=
         total amount diposed for burning+total amount separated
     Units: kg/year

(162)   waste per capita per year nwep=
         solid waste generation per capita
     Units: kg/(year*people)

****
  ."9 Computed garbage bag charge"
****

(164)   actual number garbage bags=
         total amount diposed for burning/actual weight garbage bag
     Units: bag/years

(165)   adj gbc=
         ((indicated garbage bag charge*no price burning after 2003-garbage bag charge)/adj time gbc)*
     Switch price for burning
     Units: CHF/(years*bag)

(166)   adj time gbc = 0.5
     Units: years

(167)   assumed number garbage bags=
         total amount diposed for burning/assumed weight per garbage bag
     Units: bag/years

(168)   assumed weight per garbage bag = 3
     Units: kg/bag

(169)   bag charge policy = IF THEN ELSE(Time>1990,1 , 0)
     Units: Dmnl

(170)   garbage bag charge= INTEG (
         adj gbc, 0)
     Units: CHF/bag

(171)   garbage bag charge exogenous=
         (price for burning real data*assumed weight per garbage bag)
     Units: CHF/bag

(172)   indicated garbage bag charge=
         (zidz(cost swm that should be covered by bag charge,assumed number garbage bags))*bag charge policy
     Units: CHF/bag

(173)   no price burning after 2003=
                 (IF THEN ELSE(Time > 2003, 0 , 1))*Switch on no price burning after 2003 + 1*(1-Switch on no price
                 burning after 2003)
     Units: Dmnl

(174)   price burning endogenous=

(garbage bag charge/actual weight garbage bag)
Units: CHF/kg

(175)   Switch to computed price exogenous = 0
Units: Dmnl [0,1,1]

****

 ."91 Cost solid waste management"
****

(177)   capacity in collecting points for recovering= INTEG (
capacity building-depreciation,0)
Units: kg/year

(178)   cost swm that should be covered by bag charge=
total cost for waste management-revenue from separated material-revenue from tax
Units: CHF/year

(179)   effect of impurity on recycling unit cost=
z effect of impurity on recycling cost(fraction impurity)
Units: Dmnl

(180)   effect of number recycling streams on recycling unit cost=
          z effect of number recycling streams on unit cost (zidz (Initial number recycling streams, effective nr recycling
          streams))
Units: Dmnl

(181)   Incineration cost per unit = 0.23
Units: CHF/kg [0.1,0.23,0.05]

(182)   Recycling cost per unit = 0.1
Units: CHF/kg [0,0.5,0.05]

(183)   revenue from separated material=
av amount separated*price separation
Units: CHF/year

(184)   revenue from tax=
(z revenue from tax(Time))
Units: CHF/years

(185)   tot var cost for separated material=
((total amount separated - capacity in collecting points for recovering) *unit cost for separated material)
Units: CHF/years

(186)   tot var cost for waste disposed for burning=
(Incineration cost per unit+unit cost for collecting burnable material)*total amount disposed for burning
Units: CHF/years

(187)   total amount disposed for burning=
          nonrecyclable disposed for burning by nwep+nonrecyclable disposed for burning by nwiep+nonrecyclable
          disposed for burning by wep+nonrecyclable disposed for burning by wiep+recyclable disposed for burning by
          nwep+recyclable disposed for burning by nwiep+recyclable disposed for burning by wep+recyclable disposed
          for burning by wiep
Units: kg/year

(188)   total amount separated=
appropriately separated by wep+appropriately separated by nwep+appropriately separated by nwiep
+appropriately separated by wiep+inappropriately separated by nwep+inappropriately separated by nwiep
+inappropriately separated by wep+inappropriately separated by wiep
Units: kg/year

(189)   total cost for waste management=
         tot var cost for waste disposed for burning+tot var cost for separated material
    Units: CHF/year

(190)   unit cost for collecting burnable material=
         0.1
    Units: CHF/kg

(191)   unit cost for collecting separated material = 0.2
    Units: CHF/kg [0,1]

(192)   unit cost for separated material=
         (unit cost for collecting separated material *effect of number recycling streams on recycling unit cost
          + Recycling cost per unit) * effect of impurity on recycling unit cost
    Units: CHF/kg

****
  ."911 Profit solid waste management"
****

(194)   accumulated total cost for waste management= INTEG (
         cost for waste management,0)
    Units: CHF

(195)   cost for waste management=
         total cost for waste management
    Units: CHF/years

(196)   non profit threshold=
         z profit threshold(Time)
    Units: CHF/year

(197)   profit solid waste management=
         (revenue from incineration waste+revenue from separated material+revenue from tax) –
              total cost for waste management
    Units: CHF/years

(198)   revenue from incineration waste=
         ((garbage bag charge*actual number garbage bags)*(1-Switch to computed price exogenous))
          + ((garbage bag charge exogenous*actual number garbage bags) * (Switch to computed price exogenous))
    Units: CHF/years

(199)   z profit threshold(
         [(1987,0)-(2020,10)],(0,0),(1987,0),(2020,0))
    Units: CHF/year

****
  ."92 Impurity"
****

(201)   av amount inappropriately separated= INTEG (
         change in average impurity, tot amount inappropriately separated)
    Units: kg/year

(202)   change in average impurity=
         (tot amount inappropriately separated-av amount inappropriately separated)/time to average waste amount
    Units: kg/(year*year)

(203)   chg in av amount separated=
         (total amount separated-av amount separated)/time to average waste amount

Units: kg/(year*year)

(204)   fraction impurity=
          zidz(av amount inappropriately separated, av amount separated)
          Units: Dmnl

(205)   time to average waste amount = 2
          Units: years

(206)   tot amount inappropriately separated=
          inappropriately separated by nwep+inappropriately separated by nwiep+inappropriately separated by wep
          +inappropriately separated by wiep
          Units: kg/year

(207)   z effect of impurity on recycling cost(
          [(0,0)-(0.2,3)],(0,1),(0.03,1.15),(0.09,1.5),(0.14,2),(0.2,3))
          Units: Dmnl

****
 ."93 Prices separation and prepaid tax revenue"
****

(209)   adj perception unit cost for separated material=
          (unit cost for separated material-perceived unit cost for separated material)/adj time separation cost and price
          Units: CHF/(kg*years)

(210)   adj price for separating=
          (perceived unit cost for separated material - price for separating) /adj time separation cost and price
          Units: CHF/(years*kg)

(211)   adj time separation cost and price = 1
          Units: year

(212)   av amount separated= INTEG (chg in av amount separated, total amount separated)
          Units: kg/year

(213)   normal unit cost of one unit of capacity building = 0.14
          Units: CHF/kg

(214)   perceived unit cost for separated material= INTEG (
          adj perception unit cost for separated material, unit cost for separated material)
          Units: CHF/kg

(215)   prepaid disposal tax 2004 = 0.2
          Units: CHF/kg

(216)   price for separating= INTEG (
          adj price for separating, 0)
          Units: CHF/kg

(217)   price separation=
          IF THEN ELSE(Time>2003, price for separating * Switch on price separation 2004, 0)
          Units: CHF/kg

(218)   revenue from prepaid disposal tax=
                    IF THEN ELSE(Time>2003, prepaid disposal tax 2004 , 0) * total amount separated * Switch prepaid
                    disposal tax
          Units: CHF/year

(219)   Switch on price separation 2004 = 0
          Units: Dmnl [0,1,1]

(220)   time to perceive revenue from pdt = 2
         Units: years

(221)   total amount appropriately separated=
         appropriately separated by nwep+appropriately separated by nwiep+appropriately separated by wep
         +appropriately separated by wiep
         Units: kg/year

(222)   z effect on cost of one unit of capacity building(
         [(0,0)-(20,10)],(0,0),(1.45,1.3),(2.5,1.7),(3.8,1.9),(5.5,2.1),(11.2,2.8),(12.8,3),(16,4),(17.4 ,4.5),
                (18.3,5.5),(20,10))
         Units: Dmnl

****
 ."94 Policy prepaid disposal tax"
****

(224)   average amount recovered material=
         SMOOTH(total amount separated,time to av amount recovered material)
         Units: kg/year

(225)   average life time local capacity = 10
         Units: year

(226)   Cap adj time = 3
         Units: year

(227)   capacity building=
         (desired cap building/Cap adj time)*fraction of desired capacity building
         Units: kg/(year*year)

(228)   cost of one unit of capacity building=
         normal unit cost of one unit of capacity building*(z effect on cost of one unit of capacity building
         (effective nr recycling streams))
         Units: CHF/kg

(229)   crowding=
         zidz(average amount recovered material , ((normal capacity for recovering
          * (1-weight on capacity)) + capacity in collecting points for recovering*weight on capacity))
         Units: Dmnl

(230)   depreciation=
         capacity in collecting points for recovering/average life time local capacity
         Units: kg/(year*year)

(231)   desired cap building=
         (depreciation*Cap adj time)+desired capacity adjustment
         Units: kg/(year)

(232)   desired capacity adjustment=
         (average amount recovered material-capacity in collecting points for recovering)
         Units: kg/year

(233)   effect of crowding=
         z effect of crowding(crowding)
         Units: Dmnl

(234)   fraction of desired capacity building=
         z frac of des capacity building(ratio of desired to max capacity)
         Units: Dmnl

(235)   Max cap building=
         zidz(perceived revenue from prepaid disposal tax,cost of one unit of capacity building)
      Units: kg/year

(236)   normal capacity for recovering=
         average amount recovered material
      Units: kg/year

(237)   perceived revenue from prepaid disposal tax=
         SMOOTH(revenue from prepaid disposal tax, time to perceive revenue from pdt)
      Units: CHF/year

(238)   ratio of desired to max capacity=
         zidz(desired cap building, Max cap building)
      Units: Dmnl

(239)   Switch prepaid disposal tax = 1
      Units: Dmnl [0,1,1]

(240)   time to av amount recovered material = 3
      Units: year

(241)   weight on capacity=
         z weight on capacity(Time)*Switch prepaid disposal tax + (0 * (1-Switch prepaid disposal tax)
)
      Units: Dmnl

(242)   z effect of crowding(
         [(0,0)-(80,2)],(0,0.8),(1,1),(2,1.2),(4,1.6),(5,1.8),(5.9,1.95),(7,2),(60,2))
      Units: Dmnl

(243)   z frac of des capacity building(
         [(0,0)-(2,1)],(0,0),(0.8,0.8),(0.95,0.9),(1.05,0.93),(1.2,0.97),(1.6,1),(2,1))
      Units: Dmnl

(244)   z weight on capacity(
         [(1987,0)-(2020,10)],(1987,0),(2000,0),(2003.65,1),(2020,1))
      Units: Dmnl

****
 ."95 Economic growth"
****

(246)   constant average income per capita = 70000
      Units: CHF/(year*person)

(247)   fractional change in sw generation per capita from economic growth=
         (zidz((potential SW generation per capita from economic growth-solid waste generation per capita),
                solid waste generation per capita))/time to adjust SW generation from economic growth
      Units: Dmnl/year

(248)   growth income=
         income per capita/income per capita normal
      Units: Dmnl

(249)   income per capita=
         constant average income per capita*(1-Switch to test economic growth)+Switch to test economic growth
         *initial income per capita*EXP(income per capita growth rate *(Time- INITIAL TIME))
      Units: CHF/(person*year)

(250)   income per capita growth rate = 0.025
          Units: Dmnl/year

(251)   income per capita normal =
          constant average income per capita*(1-Switch to test economic growth)+Switch to test economic growth
               *initial income per capita
          Units: CHF/(person*year)

(252)   initial income per capita = 35000
          Units: CHF/(year*person)

(253)   INITIAL TIME = 1987
          Units: year

(254)   potential SW generation per capita from economic growth=
          Solid waste generation per capita normal*growth income
          Units: kg/person/year

(255)   rate of change of solid waste generation per capita=
          fractional change in sw generation per capita from economic growth*solid waste generation per capita
          Units: kg/((year*person)*year)

(256)   solid waste generation per capita= INTEG (
          rate of change of solid waste generation per capita, Solid waste generation per capita normal)
          Units: kg/(person*year)

(257)   Solid waste generation per capita normal = 339
          Units: kg/(year*person) [0,339,339]

(258)   Switch to test economic growth = 0
          Units: Dmnl [0,1,1]

(259)   time to adjust SW generation from economic growth = 2
          Units: years

****
 ."96 Real data variables"
****

(261)   actual weight garbage bag =   3
          Units: kg/bag

(262)   effective nr recycling streams=
                    (increase in recycling streams*Switch change number of recycling streams) + (Initial number recycling
                    streams * (1-Switch change number of recycling streams))
          Units: streams

(263)   fraction for burning real data=
          1-fraction recovered real data
          Units: Dmnl

(264)   fraction recovered real data=
          z fraction recovered real data(Time)
          Units: Dmnl

(265)   increase in recycling streams=
          (increase in recycling streams after 2004 * Switch on increase in recycling streams after 2004)
                    + (increase number recyc stream 2000 * (1-Switch on increase in recycling streams after 2004))
          Units: streams

(266)   increase in recycling streams after 2004=

z increase in nr recycling streams 2020(Time)
Units: streams

(267)   increase number recyc stream 2000=
         z number recycling stream(Time)
Units: streams

(268)   Initial number recycling streams = 5
Units: streams [0,5,5]

(269)   price for burning real data=
         (z garbage bag charge(Time) /actual weight garbage bag)*Switch price for burning
Units: CHF/kg

(270)   recycling cost real data=
         z recycling cost(Time)
Units: CHF/kg

(271)   Switch change number of recycling streams = 1
Units: Dmnl [0,1,1]

(272)   Switch on increase in recycling streams after 2004 = 0
Units: Dmnl [0,1,1]

(273)   Switch price for burning = 1
Units: Dmnl [0,1,1]

(274)   three median smooth fraction burned=
         1-three median smooth fraction separated
Units: Dmnl

(275)   three median smooth fraction separated=
         z three median smooth fraction recycled(Time)
Units: Dmnl

(276)   z fraction recovered real data(
         [(1980,0)-(2025,1)],(1980,0.3),(1987,0.3),(1988,0.3),(1989,0.3),(1989.91,0.0877193),(1990,0.2),
            (1991,0.4),(1992,0.4),(1993,0.4),(1994,0.4),(1995,0.4),(1996,0.4),(1997,0.5),(1998,0.4),
            (1998 ,0.4),(1999,0.5),(2000,0.5),(2001,0.5),(2025,0.5))
Units: Dmnl

(277)   z garbage bag charge(
         [(1980,0)-(2020,2)],(1980,0),(1987,0),(1989.05,0),(1990.03,0),(1990.52,0.9),(1991.04,0.9),(1992.05,0.9),
            (1996.59,0.9),(1997.9,0.9),(1998.5,1.8),(1999.51,1.8),(2000,1.8),(2000.22,1.8),(2001.33,1.8),(2020,1.8))
Units: CHF/bag

(278)   z increase in nr recycling streams 2020(
         [(1987,0)-(2025,15)],(1980,5),(1987,5),(1989.22,5),(1990,5),(1991.54,6),(1993,8),(1997,8),(1998,9),
            (2001,9),(2004,10),(2007,11),(2010,12),(2014,13),(2017,14),(2019.7,14),(2025,14))
Units: streams

(279)   z number recycling stream(
         [(1980,0)-(2025,15)],(1980,5),(1987,5),(1989.22,5),(1991.54,6),(1993,8),(1997,8),(1998,9),(2001,9),
            (2008.5,9),(2013.34,9),(2019.7,9),(2025,9))
Units: streams

(280)   z recycling cost(
         [(1987,0)-(2000,2e+006)],(1987,495551),(1988,567929),(1989,622386),(1990,667097),(1991,830192),
            (1992,843181),(1993,1.02337e+006),(1994,1.0064e+006),(1995,968247),(1996,967072),
            (1997,1.01862e+006),(1998,1.08543e+006),(2000,1.1653e+006),(1.09955e+006,1999))
Units: CHF/kg

(281)   z revenue from tax(
        [(1987,0)-(2020,2e+006)],(1987,500000),(1988.61,500000),(1990.03,500000),(2020,500000))
    Units: CHF/years

(282)   z three median smooth fraction recycled(
        [(1980,0)-(2025,1)],(1980,0.27),(1987,0.27),(1988,0.27),(1989,0.26),(1990,0.26),(1991,0.37),(1992,0.41),
            (1993,0.41),(1994,0.44),(1995,0.44),(1996,0.45),(1997,0.45),(1998,0.46),(1999,0.47),(2000,0.49),(2001,0.5),
            (2001,0.5),(2025,0.5))
    Units: Dmnl

****
 .Control
****

        Simulation Control Parameters

(284)   FINAL TIME = 2020
    Units: year

(285)   SAVEPER = 1
    Units: year [0,?]

(286)   TIME STEP = 0.03125
    Units: year [0,?]

A3 List of parameters, initial values and graphs

S: Stock; C: Constant; G: Graph

	Variable name	Unit	Value	Qualification	Sens. Control
	View **Flows of people**				
S	Initial value not willing people	People	5730	Modeler defined, calibrated, tipping point	Yes
S	Initial value not willing experienced people	People	1500	Modeler defined, calibrated	No
S	Initial value willing inexperienced people	People	663	Modeler defined, calibrated	No
C	Min number unwilling to separate	People	1'100	Modeler defined, not too influential	No
C	Min number willing people to separate	People	1'100	Modeler defined, not too influential	No
C	Average time to forget	Years	5	Modeler defined, not too influential	No
C	Population	People	10705	Given data	No
	View **Time on moving from iep to ep**				
C	Min time constant on moving form iep to ep	Years	1	Modeler defined, calibrated	No
C	Time to average amount appropriately separated	Years	3	Modeler defined	No
G	Z effect of experience with separation on fime for moving from wiep to wep	Dmnl	Non-linear	Modeler defined, calibrated	-
	View **Fraction becoming willing**				
C	Max acceptable separating time	Hours/week	2	Modeler defined, highly influential and uncertain	Yes
C	Max acceptable separation cost	CHF/(year*person)	150	Modeler defined, highly influential and uncertain but not critical	No
C	Normal time per stream	Hours/(week*streams)	0.2	Modeler defined, highly influential and uncertain, Policy parameter	Yes
C	Time to perceive fraction willing to separate	Year	1	Modeler defined	No
C	Unit separation space cost	CHF/kg	0.1	Modeler defined	No
G	Z fraction from social norm	1/year	Non-linear	Modeler defined, calibrated	-
G	Z acceptable separating time	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of time cost recycling	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z max acceptable separation cost	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of separating cost	Dmnl	Non-linear	Modeler defined, calibrated	-

	View Fraction becoming unwilling				
C	Max acceptable time for burning	Hours/(person*week)	1	Modeler defined, not critical	No
C	Max acceptable cost for burning	CHF/(year*person)	180	Based on empirical evidence, influential but certain	No
C	Time per kg burning waste	Hours/kg	0.1	Modeler defined, not critical	No
G	Z fraction f social norm burning	Dmnl/year	Non-linear	Modeler defined, uncertain and relative influential	-
G	Z acceptable time burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z acceptable cost for burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of time burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of acceptable cost burning	Dmnl	Non-linear	Modeler defined, calibrated	-
	View Pool for effects on flow of people				
C	Unit space cost for burnable material	CHF/kg	0.05	Modeler defined, not critical	No
G	Z effect of waste per capita on time spent separating	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of ratio recyclable to appropriate separated	Dmnl	Non-linear	Modeler defined	-
G	Z effect of number recycling streams on unit cost	Dmnl	Non-linear	Modeler defined, calibrated, very sensitive	-
	View Separation behavior wep				
C	Normal fraction appropriately separated wep	Dmnl	0.38	Modeler defined, calibrated to real data	No
C	Normal amount inappropriately separated wep	Kg/(people*year)	0	Modeler defined, calibrated to real data	No
C	Normal fraction recyclable	Dmnl	0.44	Modeler defined, calibrated to real data	No
G	Z multiplier for recyclable material from number of recycling streams	Dmnl	Non-linear	Modeler defined, calibrated	-
	View Separation behavior wiep				
C	Normal fraction appropriately separated wiep	Dmnl	0.24	Modeler defined, calibrated to real data	-
C	Normal amount inappropriately separated wiep	Kg/(people*year)	0	Modeler defined, calibrated to real data	-
	View Inappropriately separated per nwiep				
C	Normal fraction appropriately separated nwiep	Dmnl	.2	Modeler defined, calibrated to real data	No
C	Normal amount inappropriately separated nwep	Kg/(people*year)	10	Modeler defined, calibrated to real data	No
C	Initial number recycling streams	Streams	5	Real data, policy parameter	No
G	Z multiplier for inappropriately separated from relative price burning	Dmnl	Non-linear	Modeler defined, calibrated to real data	-
G	Z effect of change in nr streams	Dmnl	Non-linear	Modeler defined, calibrated to real data	-
G	Z effect of change in nr streams on normal amount appropriately separated	Dmnl	Non-linear	Modeler defined, calibrated to real data	-
	View Separation behavior nwep				
C	Normal fraction appropriately	Dmnl	0.2	Modeler defined, calibrated to real data	No

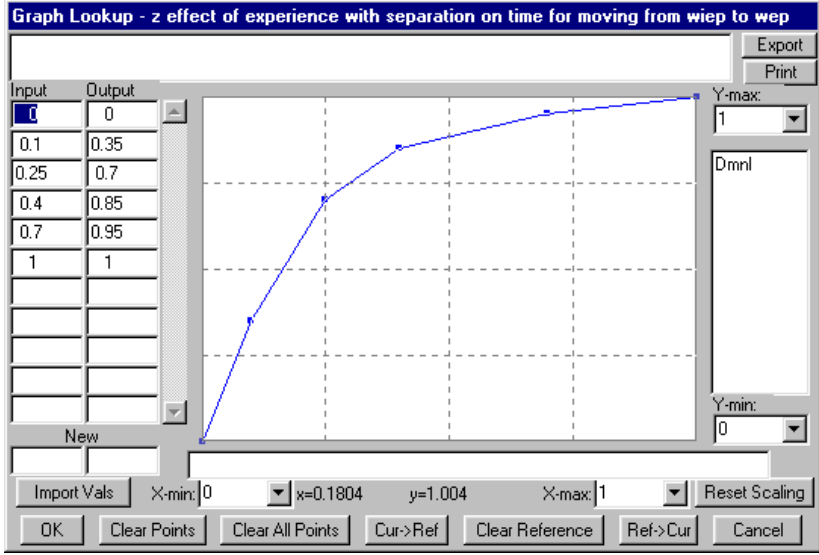|	separated nwep				
C	Normal amount inappropriately separated nwep	Kg/(people*year)	0	Modeler defined, calibrated to real data	No
	View **Computed garbage bag charge**				
C	Actual weight garbage bag charge	Kg/bag	3	Modeler defined, relevant	No
C	Assumed weight per garbage bag	Kg/bag	3	Modeler defined	No
C	Adj time garbage bag charge (gbc)	Year	0.5	Modeler defined	No
c	**View** **Cost solid waste management**				
C	Unit cost for collecting burnable material	CHF/kg	0.1	Modeler defined, policy parameter	Yes
C	Incineration cost per unit	CHF/kg	0.23	Modeler defined, scenario parameter	Yes
C	Unit cost for collecting separated material	CHF/kg	0.2	Modeler defined, policy parameter	Yes
C	Recycling cost per unit	CHF/kg	0.1	Modeler defined, scenario parameter	Yes
	View **Impurity**				
C	Time to average waste amount	Years	2	Modeler defined, scenario parameter	No
G	Z effect of impurity on recycling cost	Dmnl	Non-linear	Modeler defined, calibrated to real data, critical	-
	View **Price separation and prepaid tax revenue**				
C	Normal unit cost of one unit of capacity building	CHF/kg	0.14	Modeler defined, policy parameter	Yes
C	Prepaid disposal tax 2004	CHF/kg	0.2	Modeler defined, policy parameter	Yes
C	Time to perceive revenue from prepaid tax (pdt)	Years	2	Modeler defined, not critical	No
C	Adj. Time separation cost and price	Year	1	Modeler defined, not critical	No
G	Z effect on cost of one unit of capacity building	Dmnl	Non-linear	Modeler defined	-
	View **Policy prepaid disposal tax**				
C	Time to av amount recovered material	Years	3	Modeler defined	No
C	Average lifetime local capacity	Years	10	Modeler defined, not critical	No
C	Cap adj time	Years	3	Modeler defined, not critical	No
G	Z weight on capacity	Dmnl	Non-linear	Modeler defined, not critical	-
G	Z effect of crowding	Dmnl	Non-linear	Modeler defined, not critical	-
G	Z frac of des capacity building	Dmnl	Non-linear	Modeler defined, not critical	-
	View **Economic growth**				
C	Time to adjust SW generation from economic growth	Years	2	Modeler defined, not critical	No
C	Solid waste generation normal	Kg/(year*person)	339	Real data	No
C	Initial income per capita	CHF/(year*person)	35000	Modeler defined, not critical	No
C	Constant average income per capita	CHF/(year*person)	70000	Modeler defined, not critical	No
C	Income per capita growth rate	Dmnl	0.025	Modeler defined, not critical	No

	View **Real data variables**				
G	Z number recycling streams	Streams	Non-linear	Real data	-
G	Z increase in nr recycling streams 2020	Streams	Non-linear	Scenario	-
G	Z recycling cost	CHF/kg	Non-linear	Real data	-

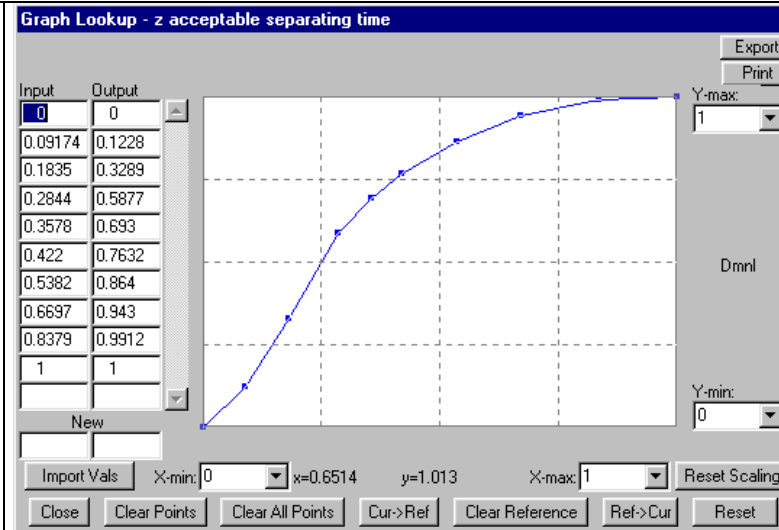| G	Z price for burning	CHF/kg	Non-linear	Real data	-
G	Z three median smooth fraction recycled	Dmnl		Computed based on real data	-
G	Z fraction recovered real data	Dmnl	Non-linear	Real data	-
G	Z revenue from tax (constant)	CHF/year	500'000	Modeler defined based on real data	-

Table: Overview of input parameters and graphical functions

A4 The graphical functions

The shape of the graphical functions is based on plausible causal assumption about the relationships between two variables. They reflect the assumption about nonlinear relationship between two variables; changes in the „input" variable (X-axis) imply nonlinear changes in the "output" variable (Y-axis). The most important reference criteria are the shape of the graph, the minimal and the maximal value. Often there is an important, well-defined reference value that the graph will pass such as the point (1,1). The "exact" values of the graph were found by calibrating the model to real data. The following list shows and explains all the graphical function in the model. Due to manual calibration processes some graph-values are unreasonable exact (to many digits after the comma). However, the modeler tried mostly to limit those digits to two.

Equation number and name	The shape of the graph	Reasoning
View "11 Time on moving from iep to ep"		
(031) Z effect of experience with separation on time for moving from wiep to wep		The Graph shows the relationship between *the <ratio average appropriately separated nwiep to wep>* (X-axis) and the effect on *<time on moving from iep to ep>* (Y-axis). If the ratio is one (both group of people have the same separation routine) then *<iep not willing to separate>* deciding to separate would flow into the stock *<ep willing to separate>* within one year (*<normal time constant on moving from iep to ep>*). But if the difference between the separation behavior of *<iep not willing to separate>* and *<ep willing to separate>*.is bigger (the ratio is getting smaller) then the learning process would take longer and therefore, also the flow from *<iep willing to separate>*to *<ep willing to separate>*.

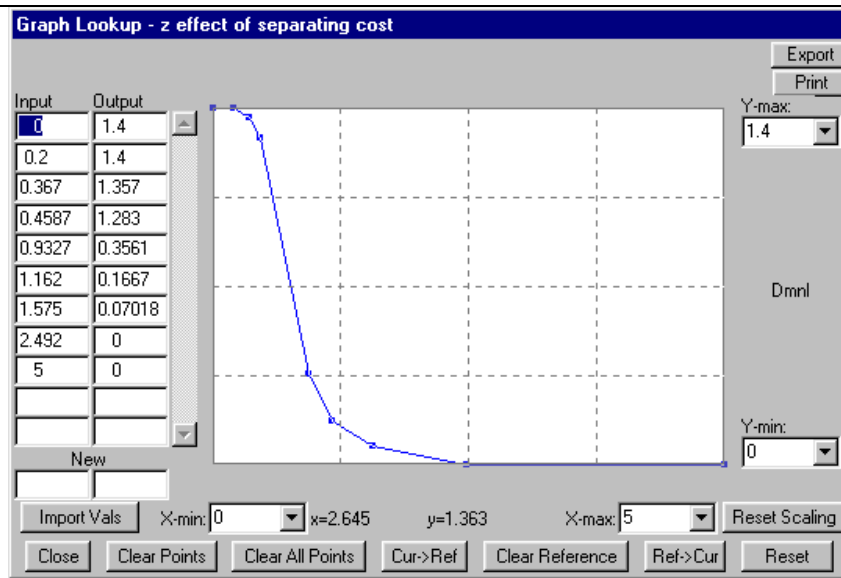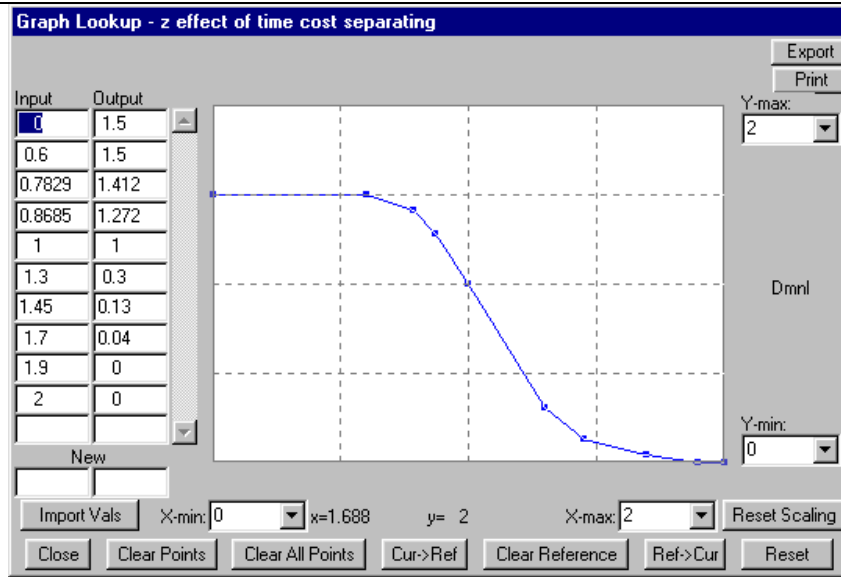| View "2 Fraction becoming willing		
(049) z acceptable separating time		The willingness to spend time for separating is a function of the *<perceived social norm separating>*. It is assumed that people have a *<maximal acceptable separating time>*, they are willing to invest in separating activities. However, this time would be lower, if the *<perceived social norm separating>* is low. The graphical function shows this relationship and discounts *<maximal acceptable separating time>* (y-axis) when the *<perceived social norm separating>* goes down (x-axis).

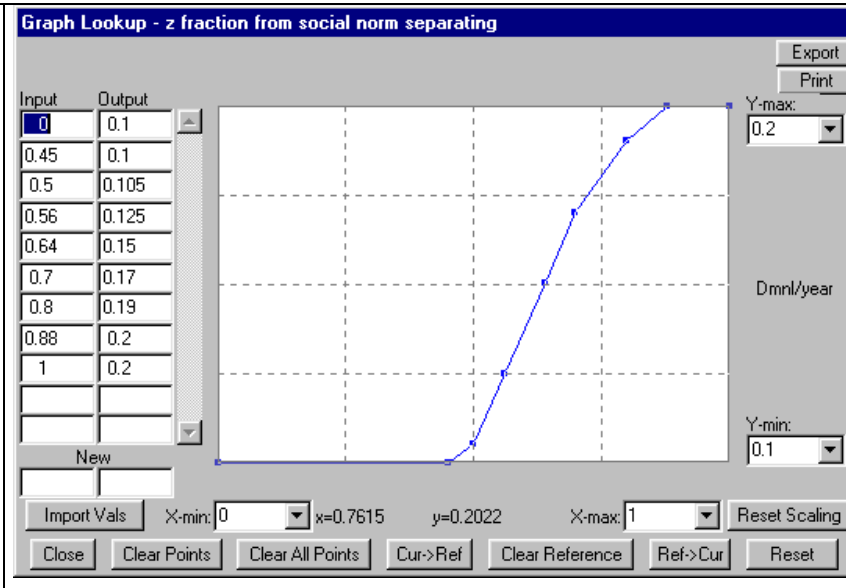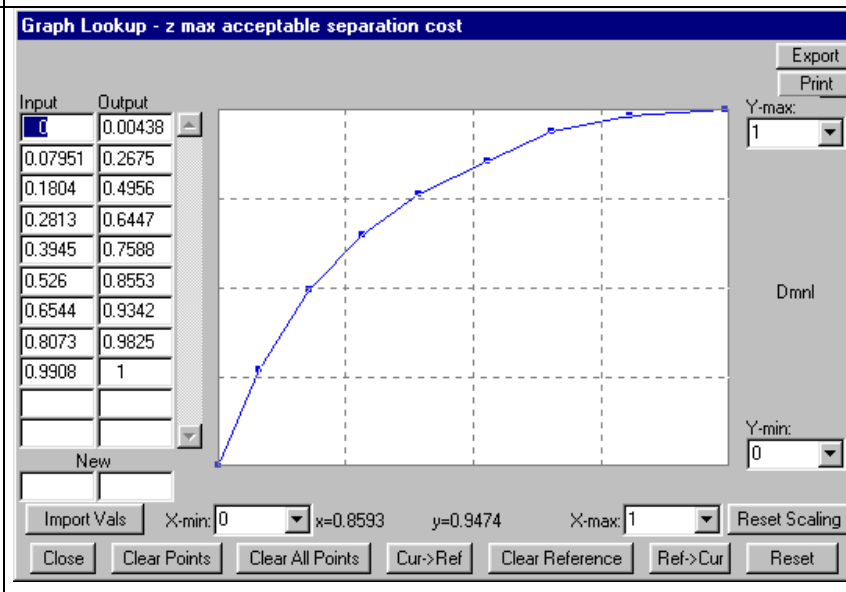| (050) z effect of separating cost | | The graphical converter *<z effect of separating cost>* computes the *<effect of separating cost>* on the diffusion process. As soon as *<separation cost>* equals or gets higher than *<acceptable separating cost per year>* (the ratio exceeds one, X-axis) the diffusion process will rapidly slow down towards zero (Y-axis). |
| (051) z effect of time cost separating | | The graphical converter *<z effect of time cost separating>* computes the *<effect of the time cost separating>* on the diffusion process. The *<effect of the time cost separating>* is normalized; when *<time spent for separating>* equals *<acceptable time for separating>*; the graphical function passes the reference point (1,1). If the time cost is very low the diffusion process will be accelerated to a maximal value of 1.5. If the required *<time spent for separating>* is twice as high as the *<acceptable time for separating>* the diffusion process will be stopped. |

(052) z fraction from social norm separating	**Graph Lookup - z fraction from social norm separating**	The *perceived social norm for separating* is a function of the *fraction willing to separate*. An increase in the *fraction willing to separate* in the municipality, will generate a stronger norm to separate, resulting in a higher number of people "willing to separate". In the decision function this idea is represented in a non-linear function. Given the obvious "disposal - or environmental problems" it is reasonable to assume that a small "normal" fraction of people will become willing to separate even when they perceive no or only a minimal social norm to do so. However, a social norm can only be effective if there is recyclable material in the waste. The *ratio recyclable to appropriate* would diminish or shut down the influence of the social norm on the diffusion process.

Input / Output:

Input	Output
0	0.1
0.45	0.1
0.5	0.105
0.56	0.125
0.64	0.15
0.7	0.17
0.8	0.19
0.88	0.2
1	0.2

Export / Print / Y-max: 0.2 / Dmnl/year / Y-min: 0.1

New

Import Vals X-min: 0   x=0.7615   y=0.2022   X-max: 1   Reset Scaling

Close Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Reset

---

(053) z max acceptable separation cost	**Graph Lookup - z max acceptable separation cost**	This graphical function computes the *acceptable separating cost per year*. Here again a low *perceived social norm separating* (X-axis) discounts the *acceptable separating cost per year* (Y-axis). It is probable that if all people are willing to separate they would be willing to bear separating cost that are near their max "threshold of pain". This threshold is set to 150 CHF/(years*person). This value is modeler defined but empirical data give evidence that it is reasonable (Bischof, 2003:54). If there is *perceived social norm separating* it is assumed that the people would not be willing to pay anything.

Input / Output:

Input	Output
0	0.00438
0.07951	0.2675
0.1804	0.4956
0.2813	0.6447
0.3945	0.7588
0.526	0.8553
0.6544	0.9342
0.8073	0.9825
0.9908	1

Export / Print / Y-max: 1 / Dmnl / Y-min: 0

New

Import Vals X-min: 0   x=0.8593   y=0.9474   X-max: 1   Reset Scaling

Close Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Reset

---

View "3 Fraction becoming

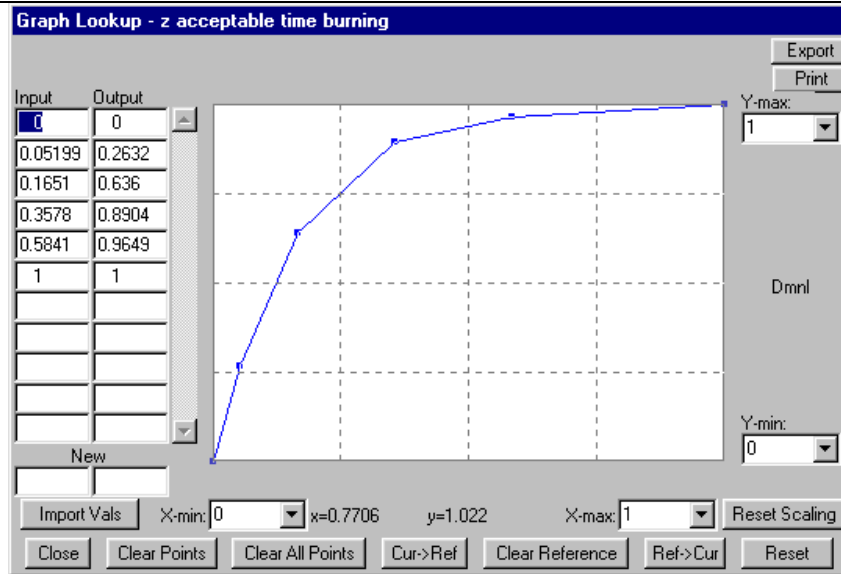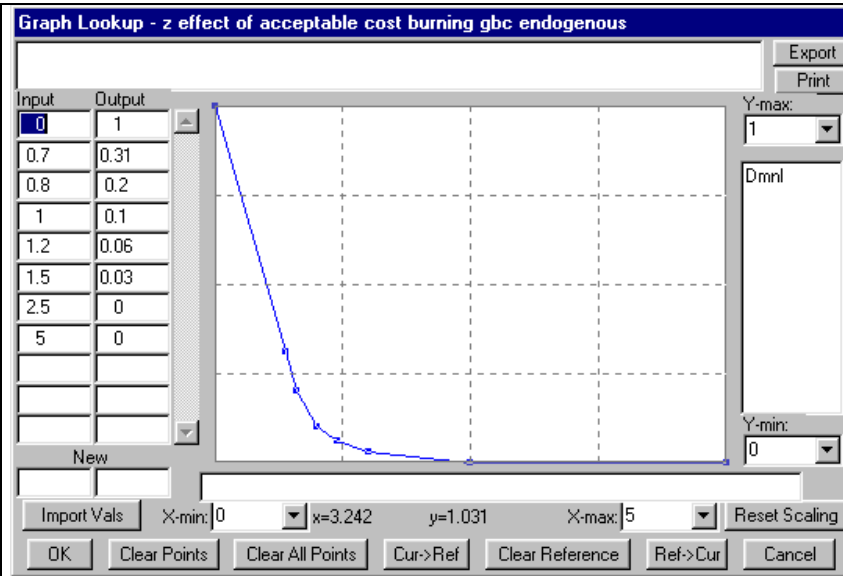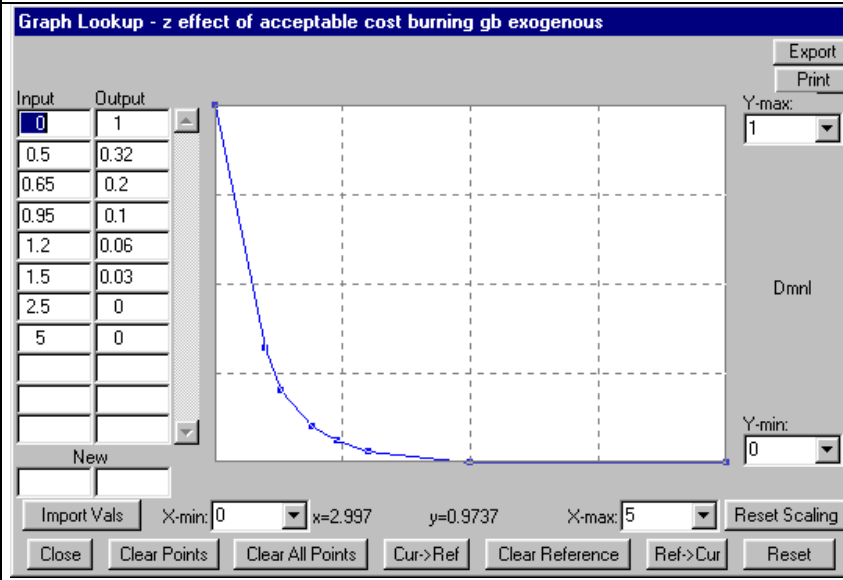| unwilling"		
(070) z acceptable cost for burning		This graph reflects the assumption that the *<perceived social norm burning>* (X-axis) discounts the *<acceptable unit costs for burning>*. The shape of the curve implies that if less people are willing to accept a polluter pay principle the lower would be the *<acceptable unit cost for burning>* (Y-axis). However, it is assumed that there will be a low minimal price people would pay for a disposal service if they would not have an alternative choice (lowest discount value).
(071) z acceptable time burning		This graph reflects the effect of the *<perceived social norm burning>* (X-axis) on the willingness to invest time into activities to sort out the burnable material *<acceptable time burning>* (Y-axis), (see also *<z acceptable separating time>*).
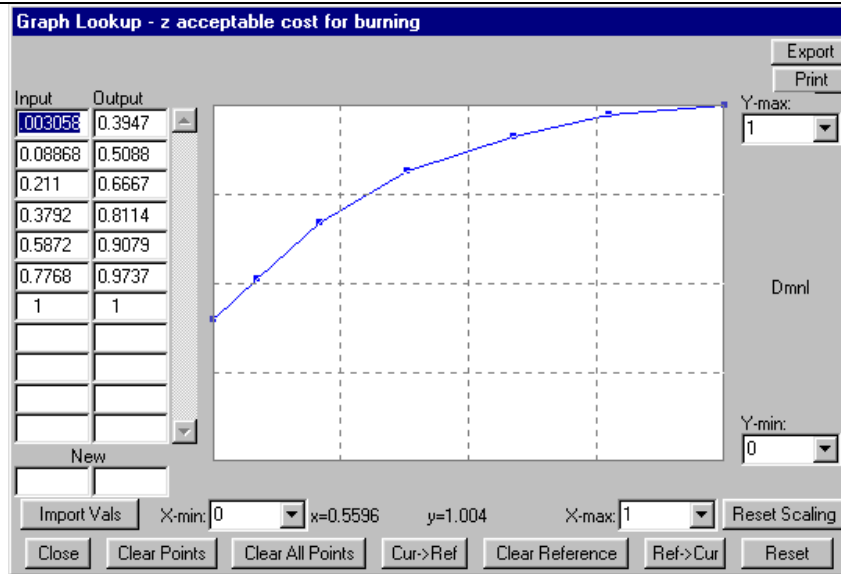
Graph Lookup - z acceptable cost for burning

Input	Output
.003058	0.3947
0.08868	0.5088
0.211	0.6667
0.3792	0.8114
0.5872	0.9079
0.7768	0.9737
1	1

Y-max: 1 Dmnl Y-min: 0
X-min: 0   x=0.5596   y=1.004   X-max: 1

Graph Lookup - z acceptable time burning

Input	Output
0	0
0.05199	0.2632
0.1651	0.636
0.3578	0.8904
0.5841	0.9649
1	1

Y-max: 1 Dmnl Y-min: 0
X-min: 0   x=0.7706   y=1.022   X-max: 1

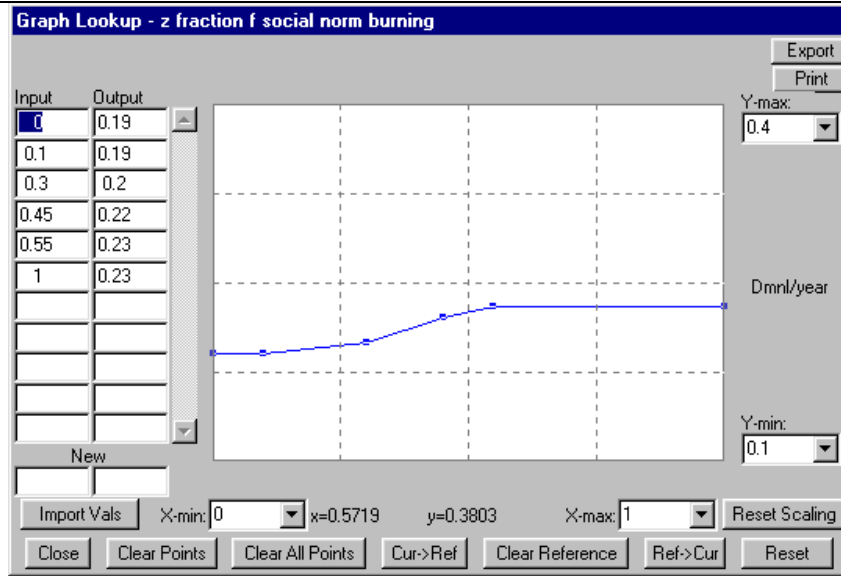|		
(072) z effect of acceptable cost burning gbc endogenous	**Graph Lookup - z effect of acceptable cost burning gbc endogenous** Export / Print Input / Output 0 / 1 0.7 / 0.31 0.8 / 0.2 1 / 0.1 1.2 / 0.06 1.5 / 0.03 2.5 / 0 5 / 0 Y-max: 1 Dmnl Y-min: 0 New Import Vals X-min: 0 x=3.242 y=1.031 X-max: 5 Reset Scaling OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel	The graph computes the *<effect of burning cost>* on the *<fraction becoming unwilling>*. If there were no burning costs there is no *<effect of burning cost>* on the *<fraction becoming unwilling>* (0,1). However, as soon as there are noticeable costs, it is assumed that this value is very sensitive (strong decline of the curve). If the *<cost for burning>* were much higher than the *<acceptable unit for burning> (<ratio cost for burning to acceptable>*, X-axis) the *<effect of burning cost>* would shut down the *<fraction becoming unwilling>* (second half part of the graph converge to zero). (The exact values of this graph are separately calibrated for the exogenously computed *<garbage bag charge>*.) (see Appendix A6)
(073) z effect of acceptable cost burning gbc exogenous	**Graph Lookup - z effect of acceptable cost burning gb exogenous** Export / Print Input / Output 0 / 1 0.5 / 0.32 0.65 / 0.2 0.95 / 0.1 1.2 / 0.06 1.5 / 0.03 2.5 / 0 5 / 0 Y-max: 1 Dmnl Y-min: 0 New Import Vals X-min: 0 x=2.997 y=0.9737 X-max: 5 Reset Scaling Close Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Reset	This graph has the same function as the graph *<z effect of acceptable cost burning gbc endogenous>* explained above, but its values are calibrated for the exogenously given *<garbage bag charge>*
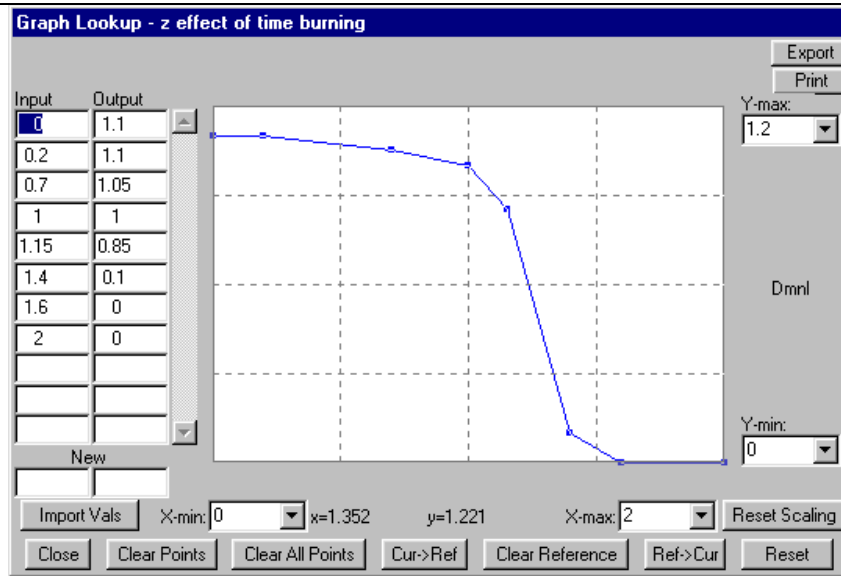
(074) z effect of time burning	**Graph Lookup - z effect of time burning**	The graphical converter *<z effect of time burning>* computes the *<effect of time cost burning>* on the *<fraction becoming unwilling>*. The *<effect of time cost burning>* is normalized; when *<time spent burning>* equals *<acceptable burning>;* the graphical function passes the reference point (1,1). If the *<time spent burning>* is very low the *<effect of time cost burning>* or *<fraction becoming unwilling>*, respectively will increase by a maximal factor of 1.1 (Y-axis). If the required *<time spent burning>* is getting 1.6 time higher than the *<acceptable time burning>* (X-axis) the *<effect of time cost burning>* or *<fraction becoming unwilling>* will become zero (Y-axis).
	Export — Print	
	Input / Output	
	0 / 1.1	
	0.2 / 1.1	
	0.7 / 1.05	
	1 / 1	
	1.15 / 0.85	
	1.4 / 0.1	
	1.6 / 0	
	2 / 0	
	Y-max: 1.2 Dmnl Y-min: 0	
	New	
	Import Vals X-min: 0 x=1.352 y=1.221 X-max: 2 Reset Scaling	
	Close Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Reset	
(075) z fraction of social norm burning	**Graph Lookup - z fraction f social norm burning**	The shape of this graphical converter computes the influence of the *<perceived social norm burning>* (X-axis) on a natural diffusion process of a trend to put the waste for burning. It will grow as soon as nearly half of the population is unwilling to separate waste increasing the *<fract becoming unwilling from social norm>* (Y-axis).
	Export — Print	
	Input / Output	
	0 / 0.19	
	0.1 / 0.19	
	0.3 / 0.2	
	0.45 / 0.22	
	0.55 / 0.23	
	1 / 0.23	
	Y-max: 0.4 Dmnl/year Y-min: 0.1	
	New	
	Import Vals X-min: 0 x=0.5719 y=0.3803 X-max: 1 Reset Scaling	
	Close Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Reset	
View "31 Pool for effects on flow		

people"
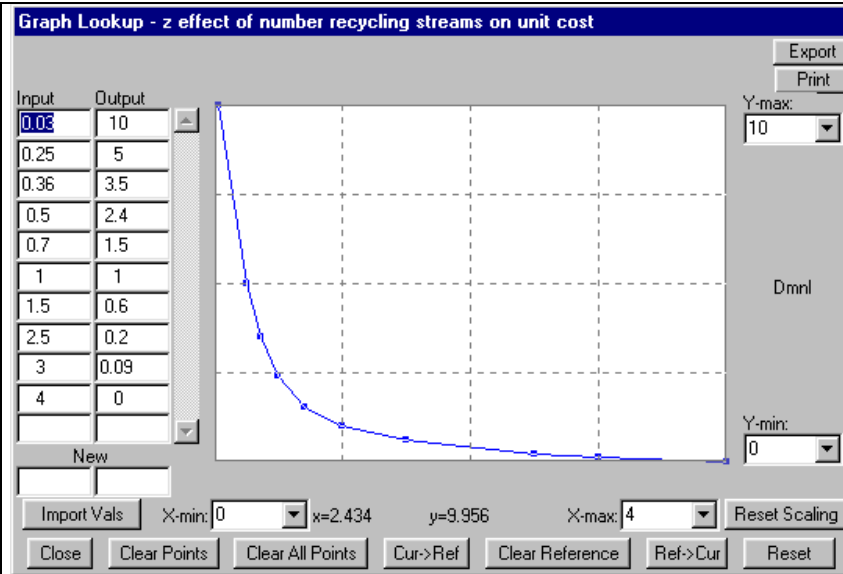
(081) z effect of number recycling streams on unit cost	Graph Lookup - z effect of number recycling streams on unit cost	This graphical converter considers the growth in cost if additional recycling streams were offered. The graph passes the reference point (1,1) when the *<the initial value number recycling streams>* equals the *<effective nr recycling streams>* (X-axis). The cost will increase sharply when further additional recycling streams will be offered (toward a factor 10) resulting in inhibiting high separation cost.

Graph Lookup - z effect of number recycling streams on unit cost

Export
Print

Input	Output
0.03	10
0.25	5
0.36	3.5
0.5	2.4
0.7	1.5
1	1
1.5	0.6
2.5	0.2
3	0.09
4	0

New

Y-max: 10
Dmnl
Y-min: 0

Import Vals   X-min: 0   x=2.434   y=9.956   X-max: 4   Reset Scaling

Close   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Reset

(082) z effect of waste per capita on time separating	Graph Lookup - z effect of waste per capita on time spent separating	The graph computes the effect of the amount waste generated on the time required for separating. The X-axis is normalized. It compares the *<waste per year per capita>* with the *<solid waste generation per capita normal>*. If the *<waste per year per capita>* equals the *<solid waste generation per capita normal>* the curve passes the reference point (1,1). If the actual amount *<waste per year per capita>* exceeds the normal amount *<solid waste generation per capita normal>*, the required *<time spent for separating>* will be multiplied by a decreasing growing factor (*<effect of waste per captia on time spent separating>*, y-axis). Once the household has adjusted their separating activities to a "large waste amount" a further increasing in the amount will not require significant more separating time.
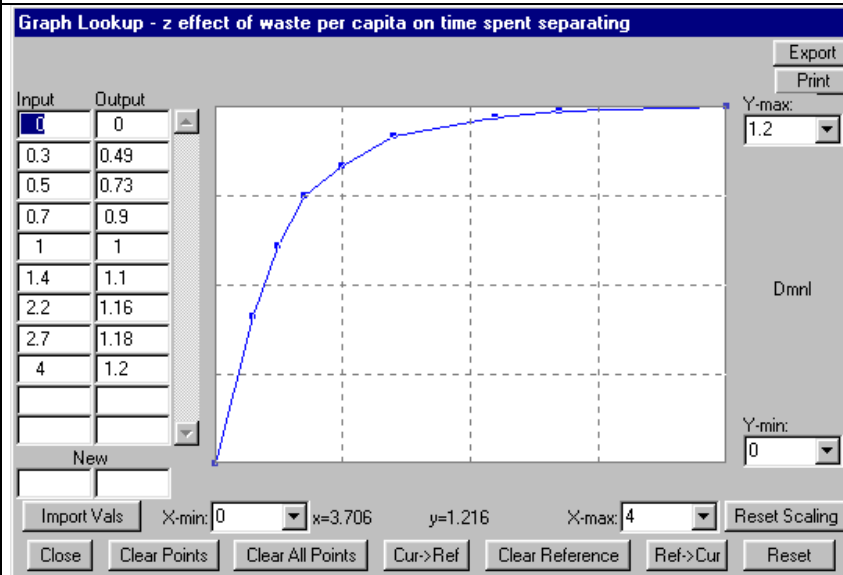
Graph Lookup - z effect of waste per capita on time spent separating

Export
Print

Input	Output
0	0
0.3	0.49
0.5	0.73
0.7	0.9
1	1
1.4	1.1
2.2	1.16
2.7	1.18
4	1.2

New

Y-max: 1.2
Dmnl
Y-min: 0

Import Vals   X-min: 0   x=3.706   y=1.216   X-max: 4   Reset Scaling

Close   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Reset

| (083) z effect of ratio recyclable to appropriately separated | | This graphical function computes the effect of a certain perceived effectiveness of the separation behavior on the diffusion process becoming willing to separate. If there is a low perceived effectiveness of the separation activities (ratio *<total amount recyclable materil>* over *<total amount appropriately separated>,-* X-axis) the *<fract becoming willing from social norm separating>* will be reduced (Y-axis). |

Graph Lookup - z effect of ratio recyclable to appropriately separated

Input	Output
0	0
0.07	0.03
0.2	0.9
0.26	0.97
0.33	1
2	1

Y-max: 1
Dmnl
Y-min: 0

X-min: 0   x=2.043   y=0.7763   X-max: 2

Import Vals   Reset Scaling
OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

View "4 Separation behavior wep"		
(094) z multiplier for recyclable material from number of recycling streams		This graph shows the relationship between the number of recycling streams and the *<normal amount appropriately separated wep>*. An increase in *<effective nr recycling streams>* (normalized X-axis) leads to a decreasing growth in the *<normal amount appropriately separated wep>* (Y-axis: growth-factor).
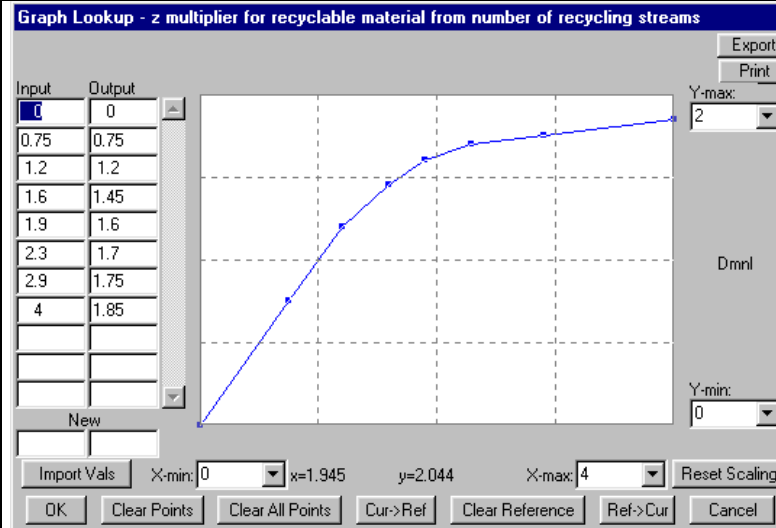
View <61 Inappropriately separated per nwiep"		
(121) z effect of change in nr streams	**Graph Lookup - z effect of change in nr streams** Export Print Input Output 0 0 1 1 5 2 Y-max: 3 Dmnl Y-min: 0 New Import Vals X-min: 0 x=4.067 y=3.066 X-max: 5 Reset Scaling OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel	In this graph the assumption is made that an increase in the *<effective nr recycling streams>* increases the fraction *<inappropriately separated per nwiep>*.

(122) z effect of change in nr streams on normal amount appropriately separated	**Graph Lookup - z effect of change in nr streams on normal amount appropriately separated**	This graph reflects the assumption that an increase in the *<effective nr recycling streams>* also would weakly effect the *<normal amount appropriately separated nwiep>*.

Graph Lookup - z effect of change in nr streams on normal amount appropriately separated

Export
Print

Y-max: 1.1

Input	Output
0	0
1	1
1.16	1.04
1.45	1.07
4	1.1

Dmnl

Y-min: 0

New

Import Vals   X-min: 0   x=4.049   y=0.5934   X-max: 4   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel
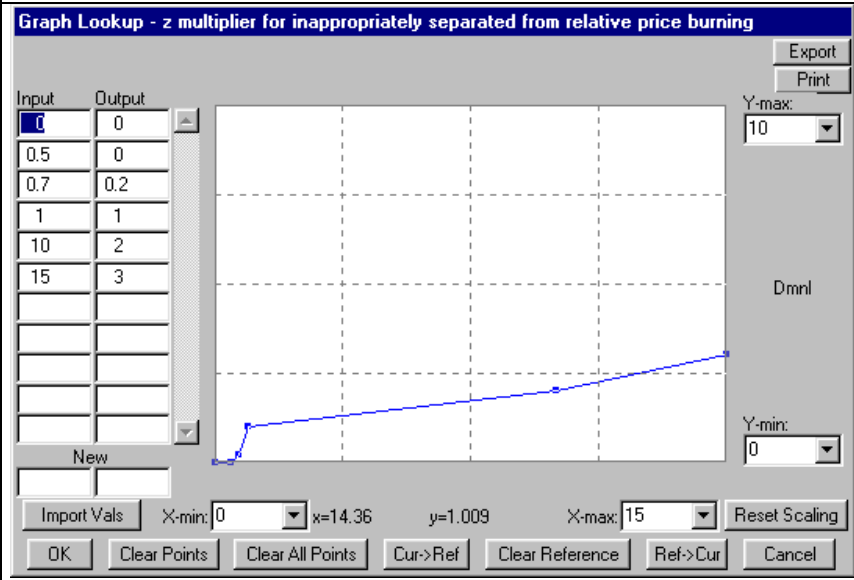
(123) z multiplier for inappropriately separated from relative price burning	**Graph Lookup - z multiplier for inappropriately separated from relative price burning**	This graphs computes the amount *<inappropriately separated per nwiep>* in relation to the *<relative price burning to separation>* (X-axis). As soon as the *<unit cost for burning>* exceeds the *<unit separation cost>* the amount *<inappropriately separated per nwiep>* will be multiplied by a factor over 1 (Y-axis).

Graph Lookup - z multiplier for inappropriately separated from relative price burning

Export
Print

Y-max: 10

Input	Output
0	0
0.5	0
0.7	0.2
1	1
10	2
15	3

Dmnl

Y-min: 0

New

Import Vals   X-min: 0   x=14.36   y=1.009   X-max: 15   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

View <911 Profit solid waste management		

(199) z profit threshold	**Graph Lookup - z profit threshold**
	
	Export
	Print
	
	Input Output Y-max:
	0 0 10
	1987 0
	2020 0
	
	                                 sFr/year
	
	                                 Y-min:
	New 0
	
	Import Vals X-min: 1987 x=2002 y=9.254 X-max: 2020 Reset Scaling
	OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel
		This graph is a help-line in order to visualize the zero profit threshold.

View <92 Impurity″		
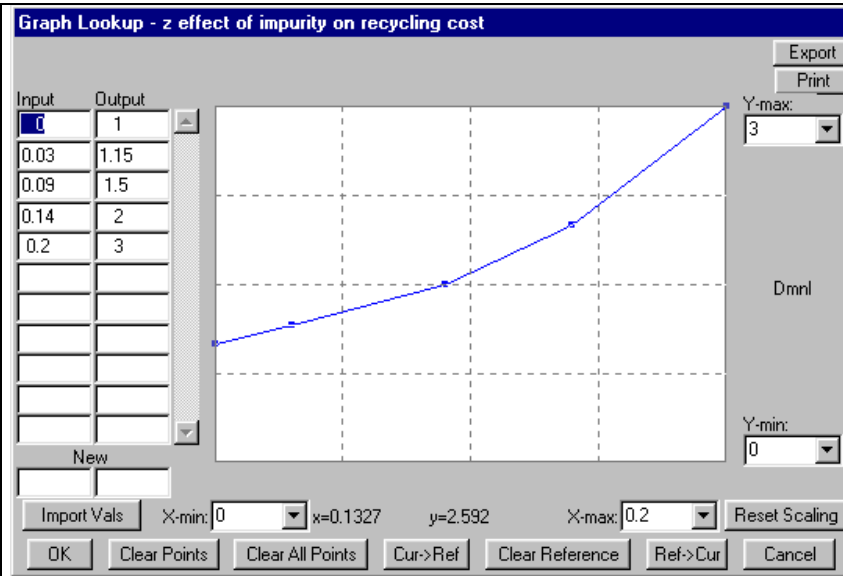
(207) z effect of impurity on recycling cost	Graph Lookup - z effect of impurity on recycling cost	With this graphical converter the effect of *<fraction impurity>* (X-axis) on the *<unit for separated material>* will be computed *(<effect of impurity on recycling unit cost>*, Y-axis).

Graph Lookup - z effect of impurity on recycling cost

Export Print

Input	Output
0	1
0.03	1.15
0.09	1.5
0.14	2
0.2	3

Y-max: 3

Dmnl

Y-min: 0

New

Import Vals   X-min: 0   x=0.1327   y=2.592   X-max: 0.2   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

View <93 Prices separation and prepaid tax revenues"
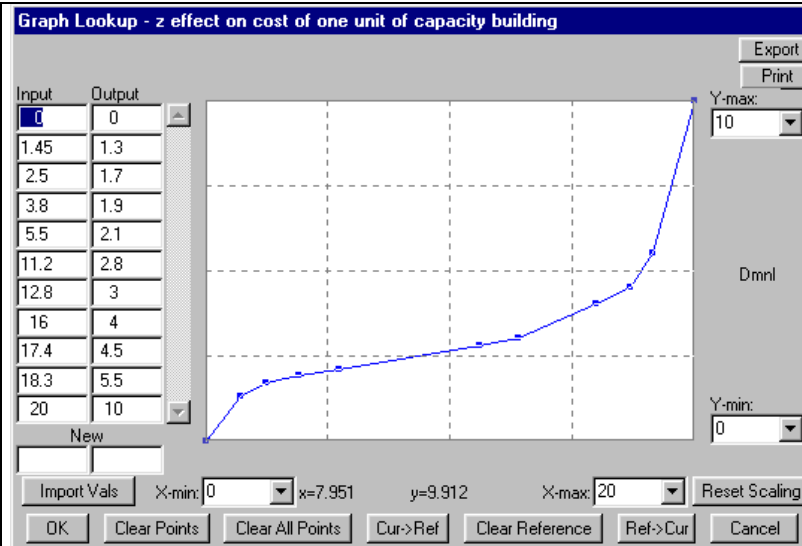
(222) z effect on cost of one unit of capacity building	Graph Lookup - z effect on cost of one unit of capacity building	The graph computes the *<cost of one unit of capacity building>* in the collecting point of retailers. The shape has been established on the assumption that in the beginning one additional recycling stream will have a stronger effect on the cost (Y-axis). Later on, for additional *<effective nr recycling streams>* (X-axis) the cost will only grow slowly once the infrastructure is established. However, if a certain limit is reached, the effect on the cost of one additional stream will be inhibiting high.

Graph Lookup - z effect on cost of one unit of capacity building

Export Print

Input	Output
0	0
1.45	1.3
2.5	1.7
3.8	1.9
5.5	2.1
11.2	2.8
12.8	3
16	4
17.4	4.5
18.3	5.5
20	10

Y-max: 10

Dmnl

Y-min: 0

New

Import Vals   X-min: 0   x=7.951   y=9.912   X-max: 20   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

View "94 Policy prepaid disposal tax"		
(242) z effect of crowding		If the *<average amount recovered material>* exceeds the *<capacity in collecting point for recovering>* there will be *<crowding>* (X-axis). The graph is establish on the assumption that *<crowding>* will increase the *<effect of crowding>* or <fraction becoming unwilling> to separate, respectively (Y-axis).
(243) z frac of des capacity building		This graph computes the *<fraction of desired capacity building>* in relation to the financially possible capacity investments and the desired capacity investment *(<ratio of desired to max capacity>,* X-axis). The *<perceived revenue from prepaid disposal tax>* restrains *<fraction of desired capacity building>* (Y-axis) as long as the possible *<max cap building>* is lower than the <desired cap building> *(<ratio of desired to max capacity>*). However, the investment will never be higher than the *<desired capacity building>* (The Y-axis never exceeds one).

| (244) z weight on capacity | | This graph is a smoothed "if else function" switching on the sub sector "policy prepaid disposal tax" after 2000. It reflects a transit period of four years in which the prepaid tax regime would be slowly established. |

Graph Lookup - z weight on capacity

Export
Print

Input	Output
1987	0
2000	0
2004	1
2020	1

Y-max: 10

Dmnl

Y-min: 0

New

Import Vals   X-min: 1987   x=2007   y=10.04   X-max: 2020   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

View <96 Real data variables"	The following graphs are the exogenous given real data. Using the table function is a convenient way for both depicting the observed real data against the simulated one and using them as model input. Thy will not be commented further on.
(276) z fraction recovered real data	

(277) z garbage bag charge	**Graph Lookup - z garbage bag charge**

Export
Print
Y-max: 2

Input	Output
1980	0
1987	0
1989	0
1990	0
1991	0.9
1991	0.9
1992	0.9
1997	0.9
1998	0.9
1999	1.8
2000	1.8

New

sFr/bag

Y-min: 0

Import Vals X-min: 1980 x=2017 y=1.684 X-max: 2020 Reset Scaling
OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel

(278) z increase in nr recycling streams 2020	**Graph Lookup - z increase in nr recycling streams 2020**

Export
Print
Y-max: 15

Input	Output
1980	5
1987	5
1989	5
1990	5
1992	6
1993	8
1997	8
1998	9
2001	9
2004	10
2007	11

New

streams

Y-min: 0

Import Vals X-min: 1987 x=2008 y=15.2 X-max: 2025 Reset Scaling
OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel

(279) z number recycling streams	**Graph Lookup - z number recycling stream**	
	Export / Print Input / Output 1980 / 5 1987 / 5 1989 / 5 1992 / 6 1993 / 8 1997 / 8 1998 / 9 2001 / 9 2009 / 9 2013 / 9 2020 / 9 New Y-max: 15 streams Y-min: 0 Import Vals X-min: 1980 x=1994 y=15.33 X-max: 2025 Reset Scaling OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel	
(280) z recycling cost	**Graph Lookup - z recycling cost**	
	Export / Print Input / Output / 4.956e+ 1988 / 5.679e+ 1989 / 6.224e+ 1990 / 6.671e+ 1991 / 8.302e+ 1992 / 8.432e+ 1993 / 1.023e+ 1994 / 1.006e+ 1995 / 9.682e+ 1996 / 9.671e+ 1997 / 1.019e+ New Y-max: 2e+006 sFr/kg Y-min: 0 Import Vals X-min: 1987 x=1998 y=2.061e+006 X-max: 2000 Reset Scaling OK Clear Points Clear All Points Cur->Ref Clear Reference Ref->Cur Cancel	

(281) z revenue from tax	Graph Lookup - z revenue from tax

Export
Print

Input	Output
1987	5e+005
1989	5e+005
1990	5e+005
2020	5e+005

Y-max:
2e+006

sFr/years

Y-min:
0

New

Import Vals   X-min: 1987   x=2009   y=2.018e+006   X-max: 2020   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

(282) z three median smooth fraction rrecycled	Graph Lookup - z three median smooth fraction recycled

Export
Print

Input	Output
1980	0.27
1987	0.27
1988	0.27
1989	0.26
1990	0.26
1991	0.37
1992	0.41
1993	0.41
1994	0.44
1995	0.44
1996	0.45

Y-max:
1

Dmnl

Y-min:
0

New

Import Vals   X-min: 1980   x=2019   y=1.031   X-max: 2025   Reset Scaling

OK   Clear Points   Clear All Points   Cur->Ref   Clear Reference   Ref->Cur   Cancel

A5 Confidence bounds of the policy experiments under different scenarios

Inertia policy 2

Best-case scenario
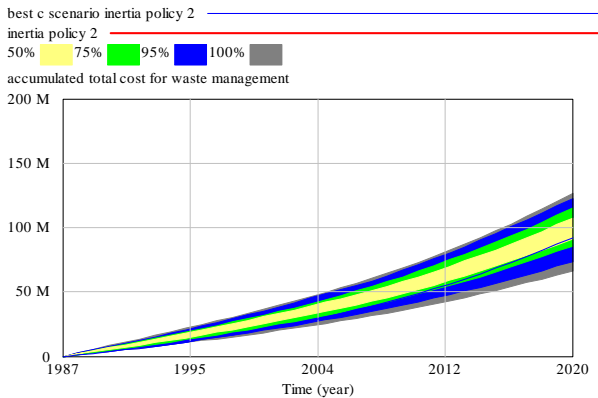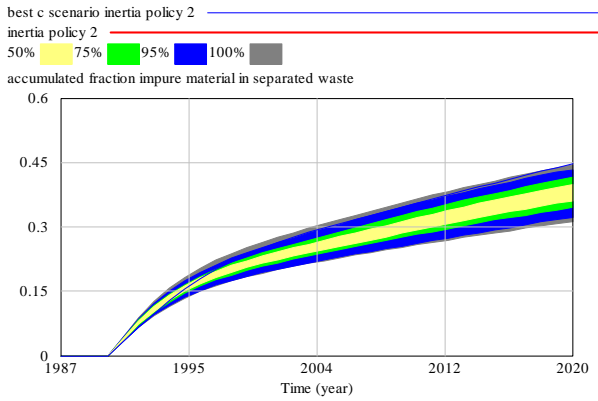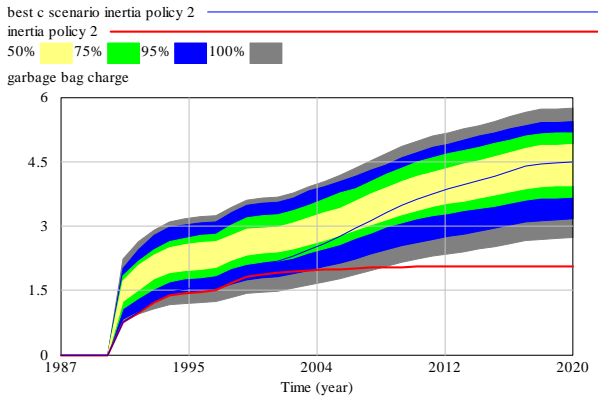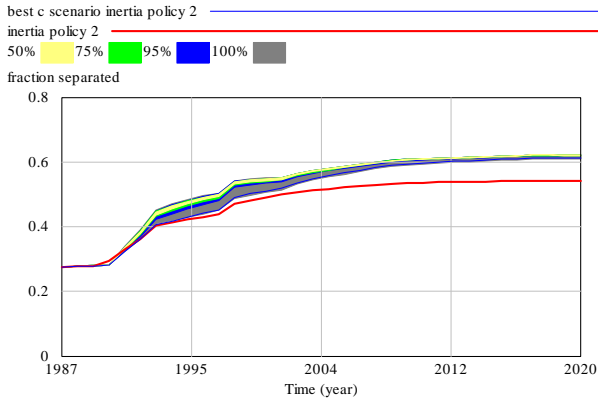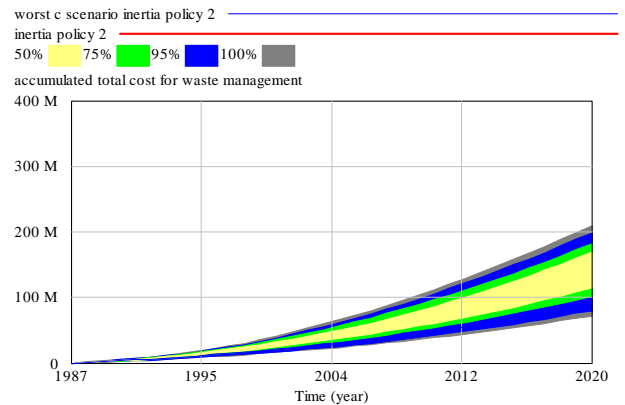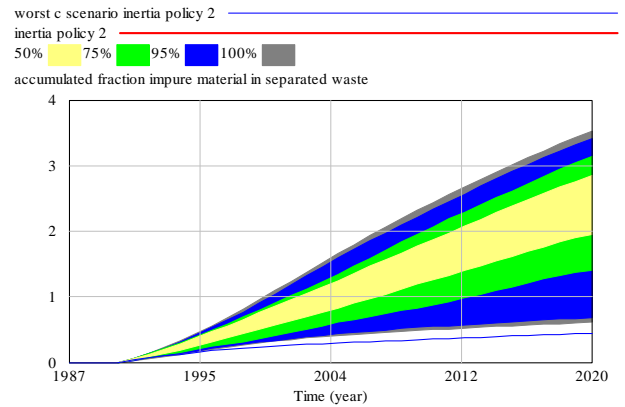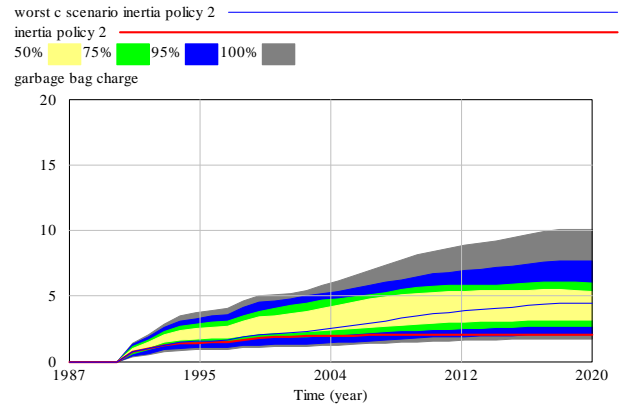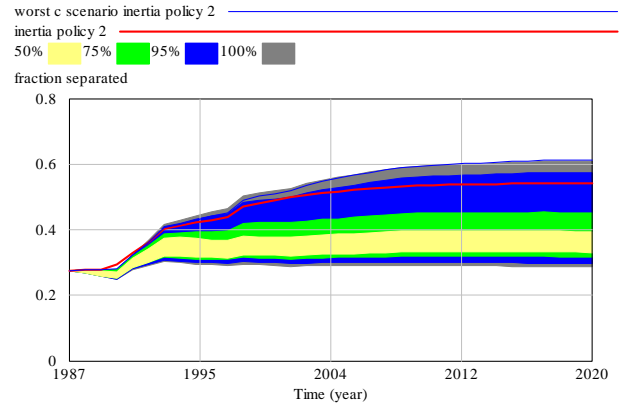
Worst-case scenario

Implement prepaid tax with flexible garbage bag charge
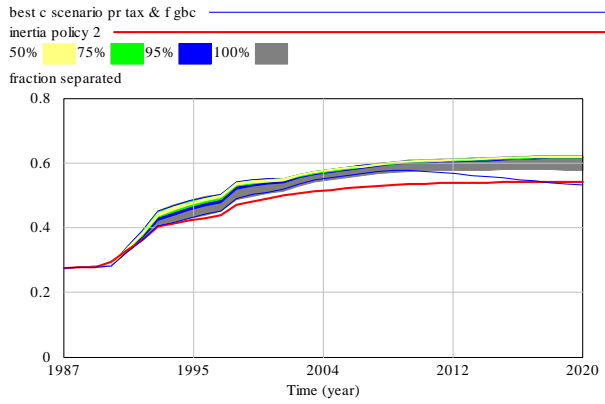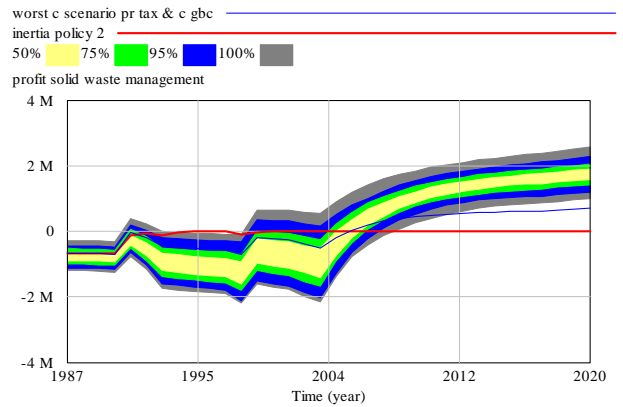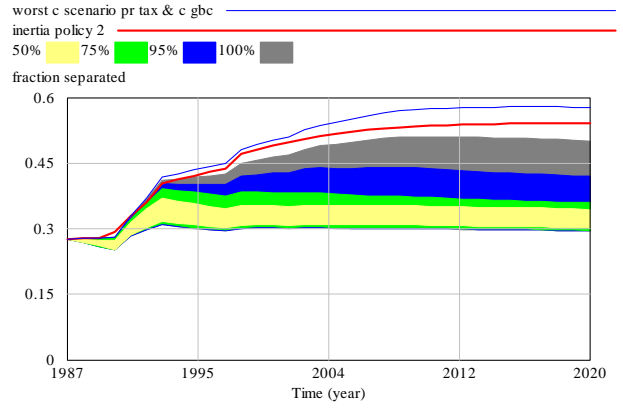
Best-case scenario

Worst-case scenario
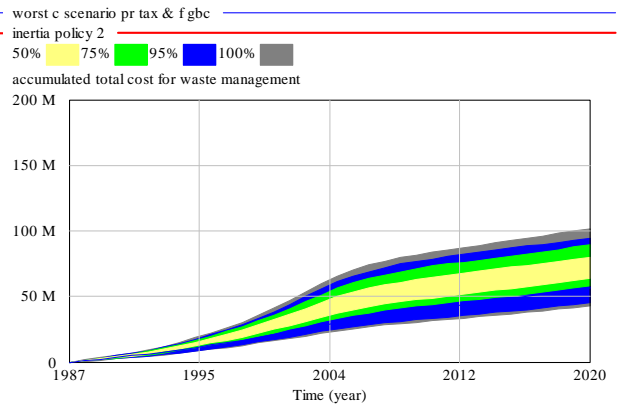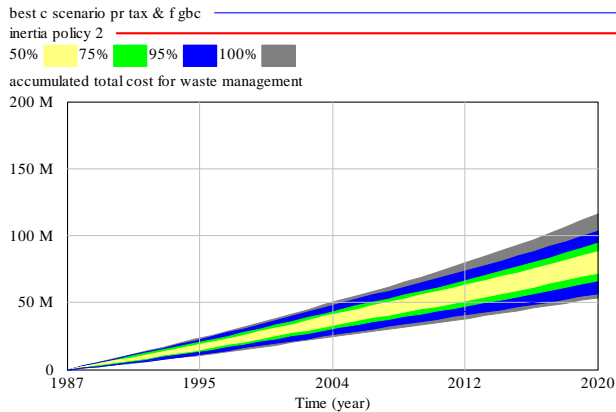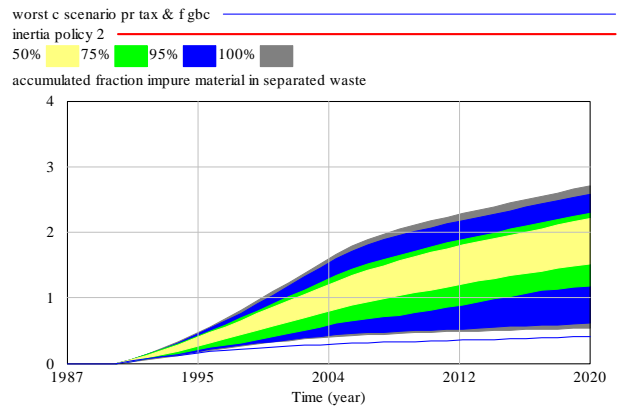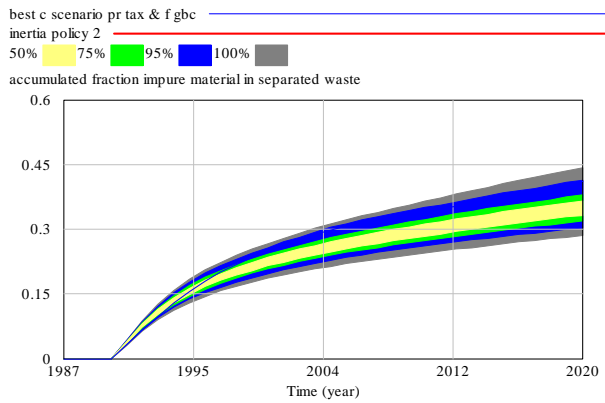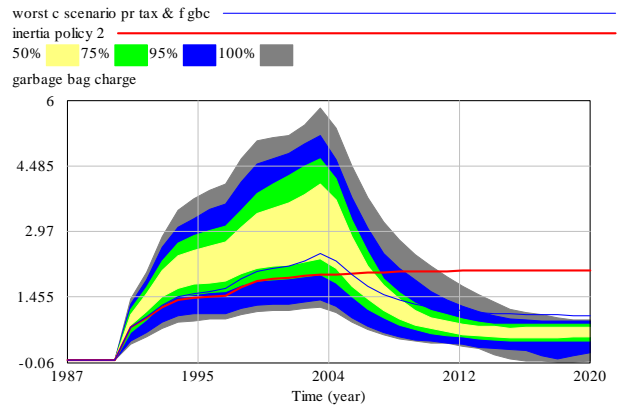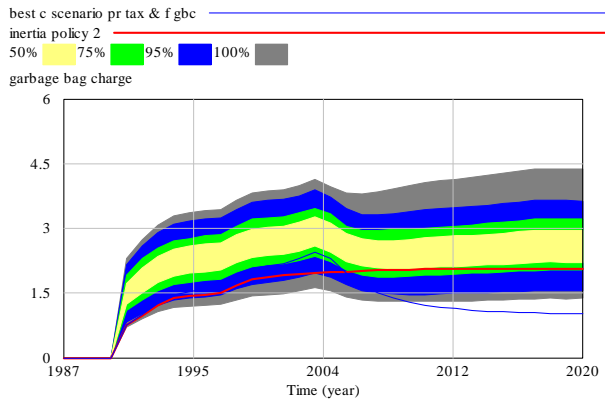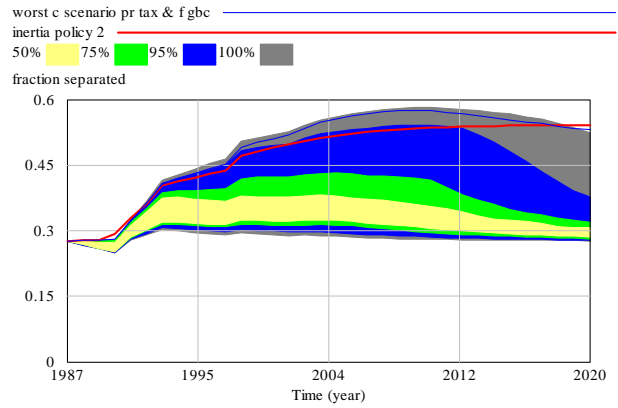
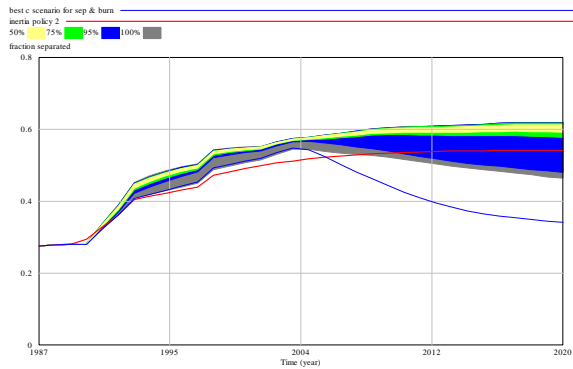## Implement prepaid tax with constant garbage bag charge
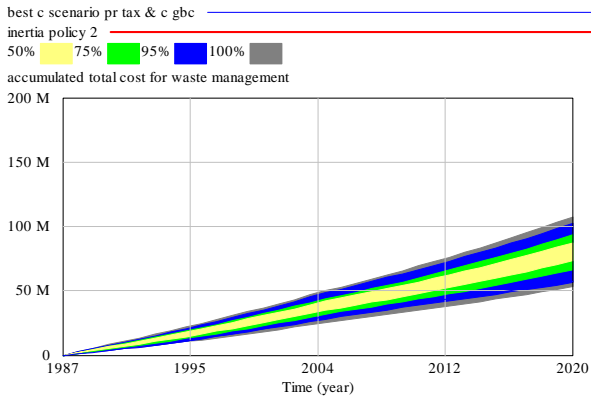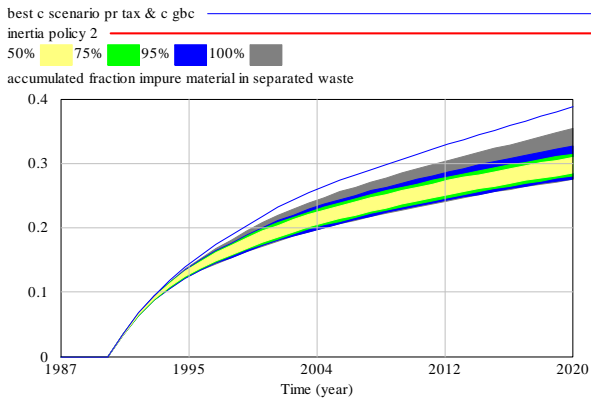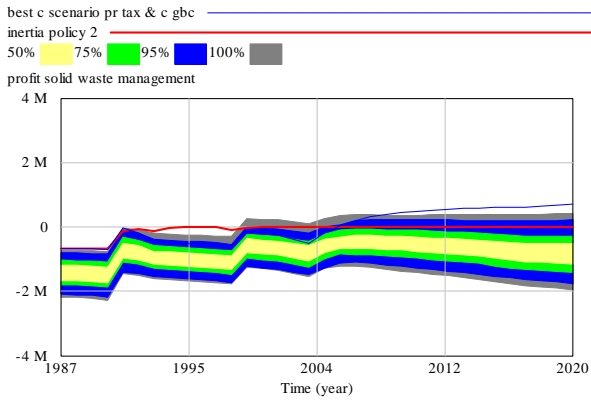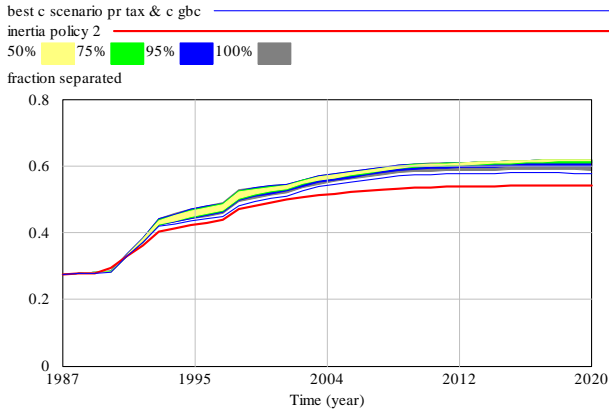
Best-case scenario

Worst-case scenario
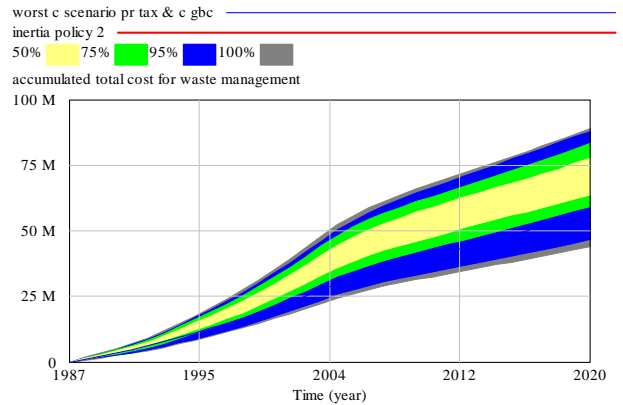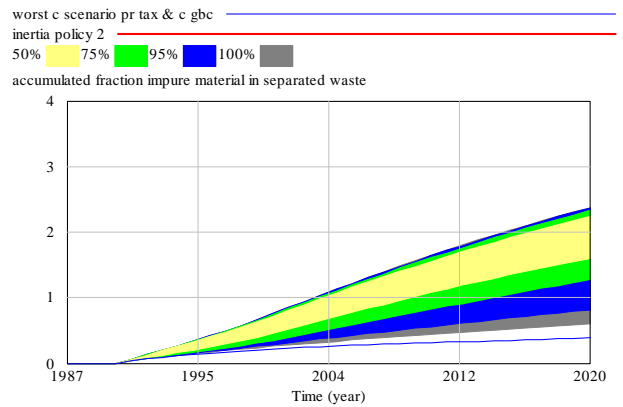
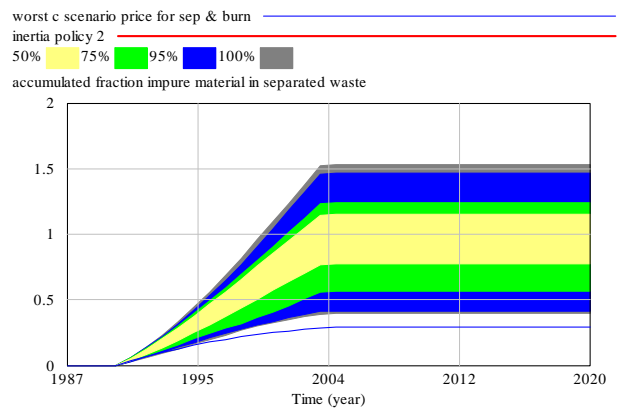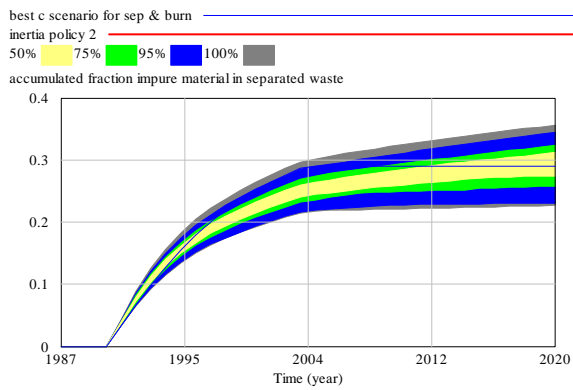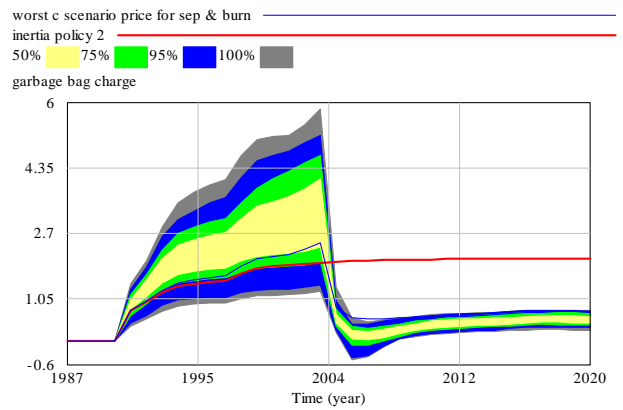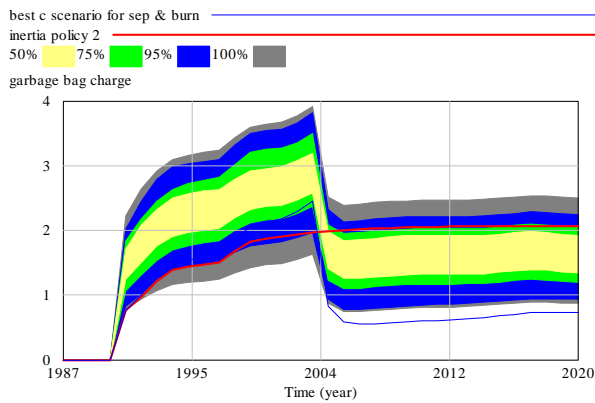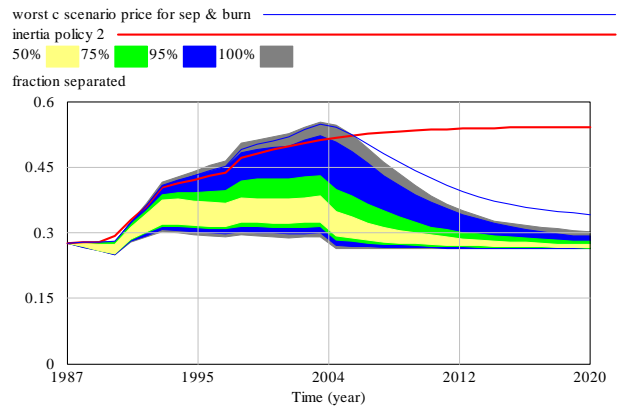# Implement price for burning and separated material and increase number recycling streams

Best-case scenario

Worst-case scenario
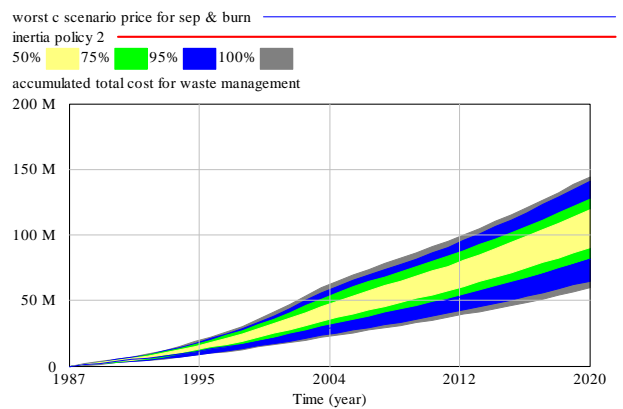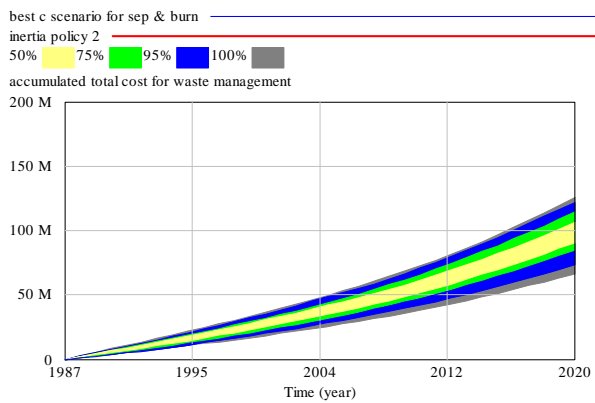
A6 A simple test for nonlinear relationships

Exemplarily, the effect of a slight variation in the loop-up-function <*z effect of acceptable cost burning*> is demonstrated. In order to reach a good fit in the **inertia policies 1** (garbage bag charge exogenous given) and **2** (garbage bag charge endogenous computed), under each policy the "adjusted" look-up-function must be used.

Fit, when price exogenous given

Fit, when price endogenous computed

Fit, when price exogenous given

Fit, when price endogenous computed

IP Strategien und Instrumente für eine nachhaltige Entwicklung
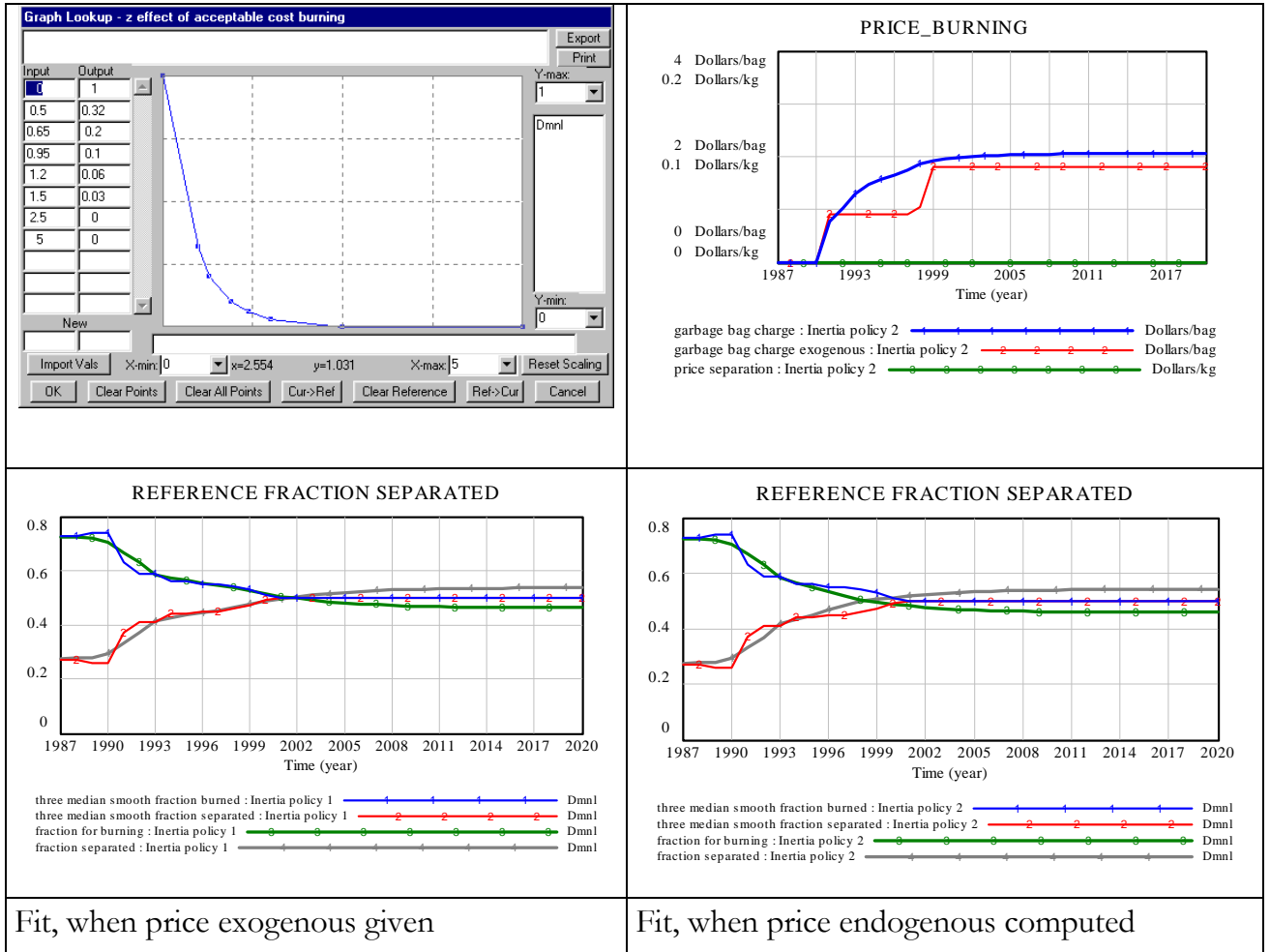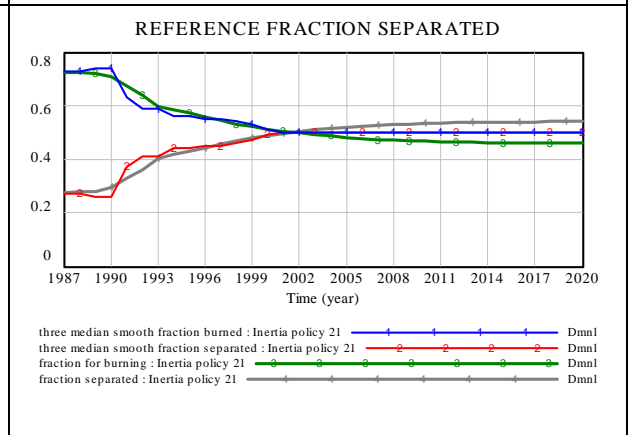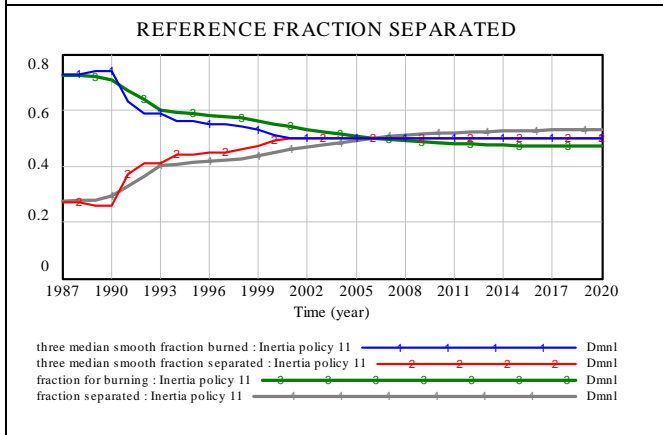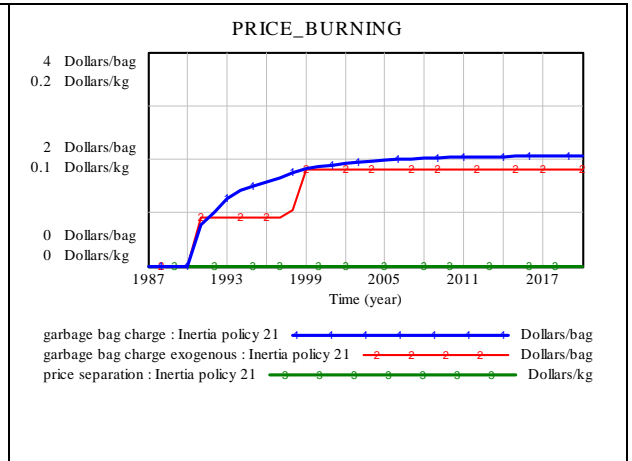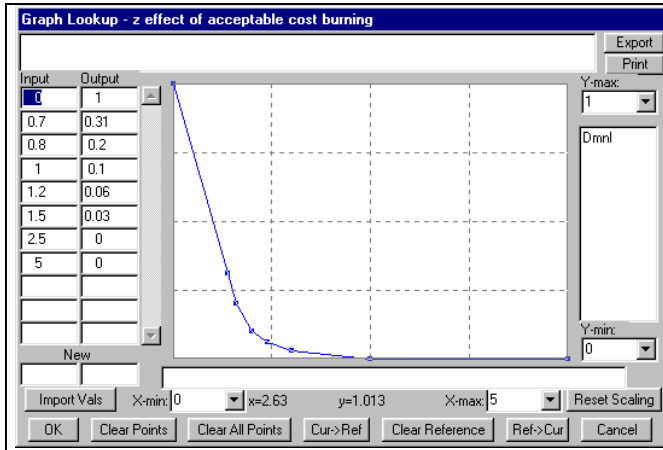
B Documentation of the workshops from the preliminary study

B1 Cooperation and agreement & functional specification

Vereinbarung und Pflichtenhefte

über die

Zusammenarbeit der Gemeinde Ittigen und der IKAÖ, Uni Bern

(Teilprojekt: Veränderungshindernisse)

Systementwicklung
Umweltverantwortliches Handeln in der Gemeinde
Ittigen

„Modell UvH"

1   Einbettung / Methode

Das Teilprojekte *„Veränderungshindernisse"* der IKAÖ, Uni Bern untersucht unter anderem die umweltrelevanten Strukturen der Gemeinde Ittigen. Diese Untersuchung ist Teil des Integrierten Projekts des Schwerpunktprogramms „Umwelt" des Schweizerischen Nationalfonds „ *Umweltverantwortliches Handeln, Strategien und Instrumente für eine nachhaltige Entwicklung: Grundlagen und Evaluation von Anwendungen, mit besonderer Berücksichtigung der Gemeindeebene."*

Die Untersuchung in der Gemeinde Ittigen baut auf dem Expertenwissen der Akteure in den fünf Handlungsbereichen Energie, Abfall, Konsum, Mobilität und Wasser/Abwasser auf. Dies setzt erstens eine Zusammenarbeit der Akteure und der Forschenden und eine Kooperation der Gemeinde voraus. Zweitens muss die verwendete Untersuchungsmethode diese transdisziplinäre Forschung ermöglichen und fördern.

Die gewählte Methode der Modellmoderation und Modellbildung nach Vennix (1996), in welcher versucht wird, das Verständnis der Experten über Zusammenhänge und Problemlagen einer Gemeinde zu erfassen, baut zugleich auf dem Wissen und den Kompetenzen der Akteure des Systems und der Forschenden auf. Die Problemanalyse und -lösung erfolgt in einem iterativen Prozess, welcher in der konkreten Ausgestaltung in verschiedenen Workshops und Vernehmlassungsrunden stattfindet.

IP Strategien und Instrumente für eine nachhaltige Entwicklung

2 Beteiligte

- Gemeinde Ittigen: Vertreten durch Martin Pauli (Umweltbeauftragter)
- IKAÖ, Uni Bern: Vertreten durch Silvia Ulli-Beer
- Experten zu den einzelnen Handlungsfeldern (noch zu bestimmen, siehe beigelegtes Blatt: Akteurvorschläge für die Expertengruppen):
  - Politiker und Beauftragte der Gemeinde
  - Forschende
  - evtl. weitere

3 Gegenseitige Verpflichtungen (Pflichtenhefte)

...gegenüber Verpflichtung der	Gemeinde	Experten	Forschende
Gemeinde		• Koordination und Anfrage der Experten • Informieren der Experten über Zusammenarbeit der Gemeinde mit der IKAÖ im Teilprojekt Veränderungshindernisse • Allfällige Entschädigung der Experten	• Vorschlagen und Vermittlung von Experten
Experten	• Vertreten der Interessen von Ittigen • Berücksichtigung der Problemlage und Gegebenheiten von Ittigen • Mitarbeit in den Workshops und den Vernehmlassungsrunden		• Mitarbeit in den Workshops und den Vernehmlassungsrunden
Forschende	• Auf Anfrage informieren über Resultate und Stand der Arbeiten • Vorstellen der Resultate in einem geeignetem Rahmen	• Verantwortlich für den Forschungsablauf und Verarbeitung der Resultate • Organisation, Durchführung und Leitung der Workshops • Weiterbearbeitung der Resultate der Workshops Zusammenstellen der Resultate und Rückmeldungen an die Experten (Vernehmlassungsrunden)	

IP Strategien und Instrumente für eine nachhaltige Entwicklung

4 Zeitlicher Rahmen

Die Workshops und die Vernehmlassungsrunden werden im Verlauf von Herbst 98 bis Sommer 99 stattfinden. Für die genauere Planung sei auf Kapitel *E Forschung und Zeitplan* im Flyer „Modell UvH", Nr. 1/März 1998 verwiesen. Es können aber je nach Verfügbarkeit der Experten und Verlauf der Forschungsschritte zeitliche Verschiebungen auftreten.

5 Aufträge an Experten

Aufträge an Experten erteilt die Gemeinde in Absprache mit den Forschenden.

6 Finanzielles

Die Entschädigung für Aufwand und Auslagen aller Beteiligter wird zwischen der Gemeinde Ittigen und der IKAÖ ausgehandelt. Eine allfällige Entschädigung für Experten wird durch die Gemeinde geregelt.

Ort und Datum: Ort und Datum:

M. Pauli   S. Ulli-Beer
Für die Gemeinde Ittigen   Für die IKAÖ

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B2 Selecting the experts

Akteurvorschläge für die Expertengruppen

Bitte tragen Sie vor allem bei den Gemeindeexperten und Gemeindepolitikern mögliche Teilnehmer der Expertengruppen ein.

Gemeindeexperten:

Im Bereich Energie könnte das Ihr Energieberater sein, oder in anderen Bereichen jemand aus Ihrer Gemeinde, welcher für diesen Bereich verantwortlich ist; dies kann auch jemand Externes sein, der von ihrer Gemeinde beauftragt wurde (z.B. ein Abfallbeauftragter).

Gemeindepolitiker:

Damit die politischen Überlegungen in jeden Teilbereich der Systemmodellierung einfliessen können, ist es wesentlich, dass wichtige Entscheidungsträger der jeweiligen Bereiche vertreten sind.

Themenexperten / Forschung

Falls Sie Akteure kennen, welche hohe fachliche Kompetenzen zu einem Themenbereich haben (evtl. gemeindespezifisch), tragen Sie diese bitte auch ein. Es können Leute aus privaten Büros, aus diversen Ämtern oder auch aus der Forschung sein.

Akteure	Verkehr	Energie	Abfall	Konsum	Wasser / Abwasser
Gemeinde-experten					
Gemeinde-politiker					
Themen-experten					
Forschung					

Bitte notieren Sie zu jedem/jeder vorgeschlagenen Akteur oder Akteurin Geschäftsadresse, Telefonnummer und Tätigkeitsfeld.

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Bereichszuordnung 1. Workshop-Runde

Datum	Kompetenzbereich Workshop 1	Experte	Background	Alternativer Kompetenzbereich
1. Workshop-Runde EV (Energie, Verkehr)	**Verkehr**	nn	BUWAL (Luftreinhaltung)	
10.Nov. 1998		nn	Bauverwaltung	Abwasser, Wasser
16.30 -19.30 Uhr	**Energie**	nn	Energieberatung	
		nn	Bauverwaltung,	Konsum
1. Workshop-Runde AKW (Abfall, Konsum, Wasser)	**Abfall**	nn	GAP (UE-Kommission)	
		nn	KEWU AG	
9.Nov. 1998		nn	GAP, Bauverwaltung, Umweltbeauftragter	
13.30-16.30Uhr		nn	Forschung, ECOPLAN	
	Konsum	nn	GAP (UE-Kommission)	
		nn	GAP, Bauverwaltung, Umweltbeauftragter	
	Wasser	nn	Brunnenmeister	
		nn	Bauverwaltung (Hochbau, Baubewilligungen, Bauökologie)	
		nn	Forschung, ECOPLAN	Energie

Im 2. Workshop werden wir die Resultate der 1. Workshop-Runde bereichsübergreifend diskutieren. Bei dieser Gelegenheit können alle Workshopteilnehmer Ihre Sicht bezüglich der fünf Bereiche einbringen.

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B3 Schedule of the first two workshops

Teilprojekt: Veränderungshindernisse

IKAÖ, Uni Bern

Silvia Ulli-Beer

Tel.: 031 / 631 39 40

Systementwicklung

_____

U mwelt V erantwortliches H andeln

M o d e l l   U v H

Weshalb wachsen die Kosten der Abfallversorgung kontinuierlich weiter, obwohl der Abfallberg scheinbar kleiner wird? Die Menge der an die KVA gelieferten Abfälle nimmt in Ihrer Gemeinde zwar ab, aber die Menge der verwertbaren Abfalle steigt und somit auch die Kosten für die Sammlung, den Transport und die Verwertung. Die Abfallpolitik wirkt sich sowohl positiv als auch negativ auf die Kosten sowie auf die Umweltbelastung aus. Ähnlich widersprüchliche erwünschte und unerwünschte Entwicklungen treten auch in den Bereichen Energie, Mobilität, Konsum, Wasser und Abwasser auf. Einerseits fällt es der Bevölkerung schwer trotz umweltpolitischer Massnahmen umweltverantwortlich zu Handeln, andererseits können umweltpolitische Massnahmen nicht lanciert werden oder starre Strukturen können kaum verändert werden.

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A Überblick: Forschungsansatz

Der Erfolg einer Politik - oder spezifischer einer Massnahme - im Umweltbereich hängt von verschiedenen Faktoren ab, die in einer Wechselwirkung zueinander stehen. Diese Faktoren und Wechselwirkungen sollen von uns in bezug auf das umweltrelevante Handeln analysiert werden.

In einem **gruppendynamischen Modellbildungsprozess mit Umweltexperten** und mit Hilfe einer **Sensitivitätsanalyse** sollen die wichtigsten Faktoren für umweltgerechtes Verhalten in den Bereichen **Abfall, Verkehr, Wasser/Abwasser, Energie** und **Konsum** herausgearbeitet werden. Die entwickelten mentalen Modelle können mit einem Software-Programm umgesetzt und ausgearbeitet werden.

Modell UvH
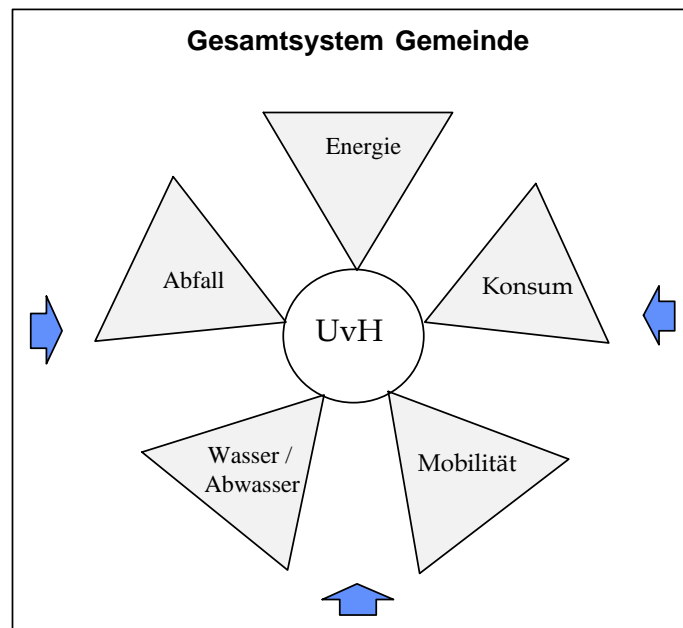
B Zielsetzungen

- Das entwickelte Modell soll so ausgebaut werden, dass durch eine Modellsimulation mit den relevanten Gemeindedaten erstens der Entwicklungstand einer Gemeinde bezüglich „Umweltverantwortlichem Handeln" bewertet und zweitens eine Policy-Analyse durchgeführt werden kann.

- Das Modell soll Einsicht in die komplexen Wechselwirkungen verschiedener Faktoren auf das „Umweltverantwortliche Handeln" in einer Gemeinde geben.

IP Strategien und Instrumente für eine nachhaltige Entwicklung

C Modellmoderation

Ein gruppendynamischer Modellbildungsprozess[72]

Der Modellbildungsprozess geht von den unterschiedlichen Theorien und Wahrnehmungen (Mentale Modelle) der Teilnehmer aus, wie verschiedene Faktoren in einem System (z.B Abfallbereich) zusammenhängen und wie sie sich entwickeln. Mit Hilfe der Systemdynamik und einem darauf aufbauenden Software-Programm (STELLA) können die verschiedenen mentalen Modelle von Akteuren zu einem einheitlichen standardisierten Modell integriert werden.

Mit dieser Methode wird das vernetzte Denken erleichtert und die häufig eindimensionale Sicht auf Probleme und Wirkungsbeziehungen erweitert. Weiter kann das Know-How der Akteure systematisch und in einer einheitlichen Sprache zusammengetragen und für eine Problemlösung fruchtbar gemacht werden.

D Die Modellbildung

Bildung von Akteurgruppen und Modellmoderation

Zu jedem Handlungsbereich (Abfall, Verkehr, Konsum, Energie und Wasser/Abwasser) wird eine Expertengruppe, bestehend aus Gemeindepolitikern, Gemeindeexperten (Bereichsverantwortliche), Forschungsvertretern und Themenexperten gebildet. Diese Expertengruppen entwickeln innerhalb einer Modellmoderation ihre mentalen Modelle. Diese Modelle werden diskutiert und in einem gemeinsamen Prozess zu einem bereichsspezifischen Teil-Modell „UvH" integriert.

Modellbildung „UvH"

Die in den Expertengruppen entworfenen Modelle werden mit dem Software-Programm STELLA in eine dynamisierbare Modellstruktur umgesetzt.

In einer ersten Phase werden die verschiedenen Variablen mittels einer Sensitivitätsanalyse bewertet.

In der zweiten Phase werden die verschiedenen Teilmodelle zu einem GESAmtmodell „Handeln und Umwelt", in welchem alle Handlungsbereiche berücksichtigt sind, zusammengefügt. Dieser Modellbildungsprozess findet unter regelmässiger Mitarbeit und Rücksprache mit den Expertengruppen statt.

In einer dritten Phase wird das Modell quantifiziert und mit Gemeindedaten kalibriert und validiert, d.h. in bezug auf die gemeindespezifischen Rahmenbedingungen geeicht und überprüft.

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[72] Vennix J. A. M. (1996): Group Modell Building. Facilitating Team Learning Using System Dynamics. John Wiley & Sons, Chincester.

IP Strategien und Instrumente für eine nachhaltige Entwicklung

In dieser Form kann das Modell „UvH" als Entscheidungshilfe für politische Massnahmen oder als Grundlage für eine vergleichende Ist-Analyse mit anderen Gemeinden in bezug auf umweltverantwortliches Handeln in der Gemeinde eingesetzt werden.

E Forschungsschritte und Zeitplan

Zeitplan	Schritte/Was:	Akteure:	Zeit-aufwand
bis Sommer 98	Vorschläge für Mitglieder der Expertengruppe Konstituierung von Expertengruppen zu den Fachbereichen: Abfall, Verkehr, Energie, Konsum, Wasser / Abwasser	Gemeindevertreter S. Ulli-Beer	
1. Workshop -Runde Sommer 98	**Modellmoderation** Entwicklung der mentalen Modelle der Expertengruppen und Integration zu einem bereichsspezifischen Teilmodell	Expertengruppe S. Ulli-Beer	2-3 Std.
	Ausarbeitung der Teilmodelle mittels STELLA	S. Ulli-Beer	
	Vernehmlassung der Teilmodelle zuhanden der Expertengruppen, Sensitivitätsanalyse	Expertengruppe	1Std.
2. Workshop Winter 98	**GESAmtmodell „UvH"** Diskussion und Ergänzung des GESAmtmodellls UvH	Alle Expertengruppen S. Ulli-Beer	2-3 Std.
	Quantifizierung des Modells „UvH" Kalibrierung und Validierung des Modells	S. Ulli-Beer	
3. Workshop Frühling 99	Diskussion und Interpretation der Resultate Anwendung des Modells	Alle Expertengruppen S. Ulli-Beer	2-3 Std.

SU 12.3.1998

IP Strategien und Instrumente für eine nachhaltige Entwicklung

B4 Scripts for the first two workshops

Im folgenden Kapitel wird kurz der Ablauf der 1.Workshoprunde erläutert. Der Ablauf und die Fragestellungen wurden vorgängig mit fünf Personen in einem Rollenspiel getestet. Dieser Pretest zeigte einerseits, dass einige Fragen genauer formuliert und erläutert werden müssen und gab andererseits der Moderatorin Übung und Sicherheit.

Für die Methodik der „Group Model Building" sind „Warum-Fragen" die Schlüsselfragen, da sie „Weil-Antworten" implizieren. Diese Antworten beziehen sich auf Ursachen, Kausalzusammenhänge und Kausalketten. *„In the context of model-building 'why' question are one of the most improtant type of questions, because they will elicit causal argumentations from the respondents" (Vennix 1996:118).* Warum-Fragen können Kausal (Ursachen) oder Final (angestrebtes Ziel) geleitete Antworten hervorrufen. Zusätzlich erweisen sich folgende Fragestellungen auch als zielführend.

Kausale Fragestellungen: Was bringt sie dazu? oder Was veranlasst Sie dazu? Welche Aspekte können bei diesem Problem unterschieden werden? Wodurch wird die Veränderung des Verhaltens erschwert?

Die Problemanalyse erweitert sich auf Kausalketten, in welchen das Problem, die Ursachen und die Konsequenzen betrachtet werden. Vennix schlägt einen möglichen systematischen Aufbau eines mentalen Modells vor.

1. Erstellen einer Liste mit potentiellen Variablen, die mit dem Problem in Verbindung stehen.

2. Identifizieren der Problemvariable.

3. Aus der Liste mit den verschiedenen Variablen unterscheiden: Variablen, welche mit den Ursachen der problematischen Situation zusammenhängen. Variablen, welche mit den Konsequenzen, den Folgen der Probleme zusammenhängen.

Diese Vorgehensweise wurde auf die Fragestellung der empirischen Untersuchung übertragen. Das eigentliche Untersuchungsobjekt ist das umweltrelevante Verhalten der Bevölkerung. Im Verlauf des Workshops sollen in erster Linie Hindernisse umweltverantwortlichen Handelns aufgezeigt werden. Folgende Fragen werden dabei wichtig.

• Was sind die unerwünschten Verhaltensweisen der Bevölkerung aus der Sicht der Gemeindeexperten?

• Welche Gründe führen zu diesen Verhaltensweisen?

• Was sind die Konsequenzen dieser Verhaltensweisen?

Hindernisse sollen aufgezeigt werden, welche die Veränderung einer umweltbelastenden Handlungsweise erschweren. Bei dieser Fragestellung wird vorausgesetzt, dass die Leute die

IP Strategien und Instrumente für eine nachhaltige Entwicklung

Absicht haben, sich umweltgerechter zu verhalten, aber es ihnen durch „Hindernisse" erschwert oder verunmöglicht wird. In diesem Kontext werden die „Veränderungshindernisse" als eigentliche Problemvariable gewählt.

- Welche Strukturen, Problemtypen erschweren eine Verhaltensveränderung?

In erster Linie sollen die umweltrelevanten Strukturen der Gemeinde und nicht personale Eigenschaften evaluiert werden. Wenn die Problemvariablen bestimmt sind, kann sich der Fokus auf erste Lösungsansätze richten. In unserem Fall sind dies Massnahmen, welche helfen „die Veränderungshindernisse" abzubauen. Diese können sich sowohl auf Konsequenzen unerwünschter Verhaltensweisen und auf Ursachen (indirekte Wirkung über den Abbau der Veränderungshindernisse), als auch auf eine unerwünschte Verhaltensweise beziehen (direkter Einfluss der Massnahme). In einer späteren Phase können dann Wechselwirkungen verschiedener Massnahmen identifiziert werden, welche die Wirksamkeit einzelner Massnahmen fördern oder abschwächen.

Konkret wurden in der ersten Workshoprunde folgende Anweisungen erteilt:

(„Die folgenden Fragen beziehen sich immer auf den Umweltaspekt *„reminder" an der Wandtafel*.)

- ✖ Welche Verhaltensweisen der Einwohner Ihrer Gemeinde im Bereich XY scheinen für Sie problematisch? Bitte schreiben Sie brainstormartig auf, was Ihnen diesbezüglich als erstes in den Sinn kommt (Lage des Hexagons beachten).

- ✖ Nennen Sie fünf problematische Verhaltensweisen.

- ✖ Nennen Sie weitere Aspekte, die mit den problematischen Verhaltensweisen zusammenhängen. Sie können dabei an die Ursachen und Konsequenzen der problematischen Verhaltensweise denken. Denken Sie dabei vor allem an die Gegebenheiten in Ihrer Gemeinde. Benutzen Sie eine andere Farbe.

- ✖ Ordnen Sie die Kärtchen so gut wie möglich den drei Feldern zu (Ursachen, problematische Verhaltensweise, Konsequenzen, siehe Tabelle) und erläutern Sie Ihre Überlegungen.

- ✖ Auf welche Probleme stossen Bürger, wenn Sie Ihr Verhalten eigentlich ändern möchten? Was sind die eigentlichen „Veränderungshindernisse". Welches sind in den umweltrelevanten Strukturen Ihrer Gemeinde Hindernisse, die einer Veränderung einer unerwünschten Verhaltensweise im Wege stehen?

Für jeden Gemeindeexperten wurde ein Packpapier mit der unten dargestellten Struktur bereitgestellt. Auf dieses wurden die Hexagon geordnet aufgeklebt (siehe Tabelle Raster für Kausalketten)

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Ursachen	problematische Verhaltensweise	Konsequenzen
Personale Ursachen		
Im Umfeld liegende Ursachen		
nicht eindeutig einer Ursachen-Wirkungsbeziehung zuzuordnen		

Tabelle: Raster für Kausalketten

Anschliessend erläuterte jeder Gemeindeexperte sein auf dem Packpapier dargestelltes mentales Modell. In der anschliessenden Diskussion wurden unterschiedliche Sichtweisen diskutiert und wichtige fehlende Elemente ergänzt. Dadurch wurde die eigentliche Problemanalyse abgeschlossen.

Für den folgenden Schritt, für die Erarbeitung erster Lösungsansätze, fehlte leider die Zeit. Folgendes Vorgehen wäre geplant gewesen.

- Die Experten schreiben ihre wichtigsten bereichsspezifischen Veränderungs-hindernisse nochmals auf ein Hexagon.
- Die Veränderungshindernisse werden erneut auf ein Packpapier geheftet.
- Welche Veränderungshindernisse wirken auf welche Bereiche.
- Mittels welchen Massnahmen können diese Veränderungshindernisse abgebaut werden?

Im Anschluss an die erste Workshoprunde wurden die aufgezeichneten Diskussionen transkribiert und erste bereichspezifische qualitative Wirkungsgefüge in der Sprache der System Dynamics gestellt. Eine erste Auswertung wurde den Gemeindeexperten zugestellt.

In einem zweiten Workshop mit allen Gemeindeexperten, wurden die ersten Wirkungsgefüge diskutiert, ergänzt und teilweise korrigiert.

Im nachhinein kann das Konzept der ersten Workshoprunden als erfolgreich bewertet werden. Eine weitere Auswertung, bei welcher die Dynamik erkennbarer Wirkungszusammenhänge aufgezeigt wird, wird im Verlauf der quantitativen Modellbildung durchgeführt.

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B5 Schedule and script of the third workshop

Bereichsübergreifende Einflussfaktoren für umweltverantwortliches Handeln

A Stand der Arbeiten

Um die in der Dokumentation der 1. Workshoprunde dargestellten Modellfragmente aus den Bereichen Abfall, Konsum, Wasser/Abwasser, Energie und Verkehr zu einem GESAmtmodell UvH zusammenfügen zu können, wurden personale und situationale Faktoren erarbeitet, welche die subjektiven Handlungsmöglichkeiten beeinflussen. Diese stellen sozusagen der kleinste gemeinsame Nenner der verschiedenen Bereiche dar. Ein Modellkonzept, welche die Modellierung leitet, wurde erarbeitet und im Schaubild Handlungsystem dargestellt.

B Ziele des 2. Workshops

- Es wird eine kurze Einführung in die Sprache der System Dynamics gegeben und ein mit dem Programm Stella aufgebautes Modell der Abfallwirtschaft demonstriert
- Die ersten Modellfragmente werden wiedererkannt, diskutiert und ergänzt.
- In Ittigen eingesetzte umweltrelevante Massnahmen werden nach einer Typologie erfasst.
- Weitere mögliche konkrete Handlungsoptionen der Gemeinde werden erarbeitet.
- Heureka: Bereichsübergreifende Massnahmen werden gefunden!

C Programm

Phase	Inhalt / Ziel	Form	Zeit bedarf
15.30 BEGRüSSUNG / EINFüHRUNG	• Dokumentation 1. Workshoprunde einordnen können. • Dokumentation 1. Workshoprunde - enthält zum einen Instrumente zur Auswertung - stellt zum anderen eine erste Umsetzung der Ergebnisse der 1.Workshoprunde in die Sprache der System Dynamics dar. Die verschiedenen Instrumente zur Auswertung werden nicht weiter erklärt, da dies den Zeitrahmen sprengen würde. Sie wurden aber trotzdem der Dokumentation beigefügt und kurz erklärt, um für alle Beteiligten doch eine gewisse Transparenz des Vorgehens schaffen zu können.		5
15.35 Einblick in die Sprache der System Dynamics	• Vorstellen Gerold Lacher (EBP) • Kennenlernen der Modellbausteine der System Dynamics. • Kennenlernen eines Abfallmodell, welches mit Stella simuliert wird.	• Gerold Lacher erklärt das Modell der Abfallwirtschaft • Demonstriert die Simulationsmöglichkeiten (Beamer und Laptop) • Kurze Diskussion	35'

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16.10 Modellkonzept Modell- fragmente	• Idee des Modellaufbaus verstehen • Die eigenen Modellfragmente können gelesen und interpretiert werden. Jede Bereichsgruppe schaut ihre Modellfragmente an, diskutiert sie in der Gruppe und notiert Fragen und Ergänzungen.	• Folie: Schaubild • Folie Hindernisse für UvH • Wirkungsgefüge: subjektive Handlungsmöglichkeiten (Beamer, Laptop) • Gruppenarbeit „Modellfragmente", • Plenum: Ergänzungen der Wirkungsgefüge	10′ 15′
16.35 Situationale und personale Faktoren	• Situationale und personale Einflussfaktoren können unterschieden werden. Innerhalb der Modellfragmente werden die unterschiedlichen Faktoren nach s oder p Faktoren gekennzeichnet. • Wirkungsketten, welche keinen direkten Einfluss auf das UvH haben werden erkannt. • Der direkte Bezug der Modellfragmente (AKW-EV) zum Wirkungsgefüge *subjektive Handlungsmöglichkeiten* wird ersichtlich.	• Gruppenarbeit; Bezeichnung der s und p Regler. • anhand der Arbeitsblätter (Folien - Einflussmöglichkeiten der Gemeinde) werden diese Eintragungen verglichen und ergänzt. • Kurze Diskussion, Ergänzungen der Modellfragmente	 20′
16.55 Einführung Instrumenten- Typologie	• Die Typologie als Syntheseprodukt: Die Strategien *Soziales Marketing und Information* werden als innovative umweltpolitische Instrumente erklärt. Konkrete upInstrumente, welche in der Gde Ittigen eingesetzt werden, werden nach der Typologie eingeordnet (BestandESAufnahme der von der Gemeinde Ittigen initiierten und eingesetzten Instrumente).	• Gruppenarbeit (bereichsspezifisch) / Arbeitsblatt *Instrumente und Strategien*, Instrumenten-Typologie: Welche Instrumente werden in Ittigen konkret in welchem Bereich eingesetzt. • Anhand der Beschreibung der Instrumenten-Typologie werden die in Ittigen eingesetzten Massnahmen erfasst.	 35′
17.30 Pause			
17.50 weitere Einflussmöglich keiten der Gemeinde Triangulatione evtl. Heureka	• Triangulation: Modellfragmente, Faktoren subjektiver Handlungsmöglichkeiten und Handlungsoptionen der Gemeinde (Instrumententypologie) • Problemlösungsansätze werden konkret genannt und umschrieben. Bereichsübergreifende Handlungsoptionen der Gemeinde werden je nach situationale oder personale Faktoren gesucht und konstruiert.	• Plenum, Beamer, Arbeitsblatt *„Einflussmöglichkeiten der Gemeinde"* Instrumententypologie Mit welchen Instrumenten kann am ehesten auf eine problematische Verhaltensweise eingewirkt werden Bereichsspezifische Lösungsvorschläge werden auf dem Blatt notiert (evtl. versucht in den Modellfragmenten einzutragen)	 60′
18.50 Ausblick 19.00	• Die erarbeiteten v. a. bereichsübergreifenden Handlungsoptionen der Gemeinde werden im Modell dargestellt. *(SU)* • Akteure und Institutionen mit welchen für die einzelnen erarbeiteten Handlungsoptionen zusammengearbeitet werden sollte, werden aufgelistet. *(Gemeindeexperten)* • Vernehmlassungsrunde *(SU < - > Gemeindeexperten)* • Umfrage: Einflussstärken versch. Faktoren, Datenbeschaffung *(SU < - > Gemeindeexperten)* • Herbst-Winter 99 Termin 3. Workshoprunde		10′

SU 8.3.99

Selbständigkeitserklärung

Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche kenntlich gemacht. Mir ist bekannt, dass andernfalls der Senat gemäss dem Gesetz über die Universität zum Entzug des auf Grund dieser Arbeit verliehenen Titels berechtigt ist.

Diese Arbeit habe ich nur an der Universität St. Gallen eingereicht.

Langenthal, im Januar 2004

Silvia Ulli-Beer

Curriculum Vitae

Silvia Ulli-Beer

Born in Langenthal, Switzerland, 29.07.1966
Married, 2 children born in 1994 and 1996

Scientific Education

2004, October	Doctor oeconomiea (Dr. oec.)
2002 -2003	Course work in Simulation for Policy Analysis at the Rockefeller College of Public Affairs and Policy and Policy at the University at Albany, SUNY, USA
2000-2002	Doctoral studies at the University of St. Gallen
1991-1998	Master in economics (lic.rer.pol), University of Berne and Geneva
1983-1988	Teacher training college in Langenthal

Work experiences and awards

2004	Research associate at the Interdisciplinary Center for General Ecology, University of Berne
2002 - 2003	Visiting Scholar at the Rockefeller College of Public Affairs and Policy at the University at Albany, SUNY, USA
2002	Award from the basic research funds of the University of St. Gallen
1997 - 2002	Junior researcher for Prof. Dr. R. Kaufmann-Hayoz at the Interdisciplinary Center for General Ecology, University of Berne, Switzerland
1998-2002	Several activities including: Consulting activity related to strategic planning for regional sustainability, planning and teaching in the continuing education program and supervising of an interdisciplinary student research project of the Interdisciplinary Center for General Ecology, University of Berne,
1991 - 1998	Accounting clerk: Trust Keiser AG, Langenthal , Switzerland Undergraduate teachings positions for adult education
1988 - 1991	Form teacher at the public school in Murgenthal, Switzerland