

Department of Social Research
University of Helsinki
Finland

OVERCOMING THE INSTITUTIONAL OBSTACLES OF INDUSTRIAL RECYCLING

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ACADEMIC DISSERTATION

To be presented, with the permission of the Faculty of Social Sciences of the University of Helsinki, for public examination in Small hall (4050), University main building, on 28 September 2015, at 12 noon.

Helsinki 2015

Publications of the Department of Social Research 2015: 16
Social and Public Policy

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Cover art: Elna Vepsäläinen (1910-2009)
Photography of the artwork: Petri Allekotte
Cover layout: Jere Kasanen

Distribution and Sales:
Unigrafia Bookstore
<http://kirjakauppa.unigrafia.fi/>
books@unigrafia.fi
PL 4 (Vuorikatu 3 A) 00014 Helsingin yliopisto

ISSN-L 1798-9140
ISSN 1798-9132 (Online)
ISSN 1798-9140 (Print)
ISBN 978-951-51-1025-1 (Online)
ISBN 978-951-51-1026-8 (Print)

Unigrafia
Helsinki 2015

ABSTRACT

The circular economy is a topical issue in public policy and environmental social science. This dissertation offers a critical study of operations intended to develop a circular economy and industrial recycling of materials. The study identifies obstacles that prevent or delay the development of industrial recycling and seeks new solutions for overcoming these obstacles.

Institutional obstacles are at the core of this work. They can be identified either as formal obstacles, such as legal or administrative problems, or as informal obstacles, such as problems related to routines or established practices. Traditionally, institutional obstacles have been considered either formal or informal. This dissertation challenges that conception and claims that often the most difficult obstacles are those that operate between the formal and the informal. Operating in between disconnects formal (administrative) institutional reality from informal (operative) institutional reality. It is challenging, if not impossible, to develop formal rules or ways of doing things related to a particular issue once the connection related to that issue has been cut off, because formal and informal realities are structurally dependent on one another.

At the same time the dissertation points out that once the disconnection has been identified, it is possible to reunite formal and informal realities. This can be done by means of an institutional feedback mechanism that fits the local circumstances. Institutional feedback means maintenance of knowledge exchange between actors and groups of actors operating in different realities. In an industrial context, institutional feedback may, for example, enable the development of new kinds of recycling opportunities and continuous intensification of the materials' utilization. Novel institutional feedback mechanisms may also offer new possibilities for overcoming obstacles in the development of recycling and the promotion of the circular economy in different sectors of society.

This dissertation consists of four case studies that investigate the management of materials and other resources in industrial units located in the Bothnian Arc region of northern Finland. The industrial units studied cover the fields of Finland's traditional basic industries: the metal, wood-processing, and chemical industries. The primary data for this study consist of interview materials, questionnaires, and documentary sources. The main points of interest are two types of recycling: 1) the utilization of different leftover materials as replacements for existing products or as raw materials, and 2) the development of completely new kinds of recycling products and innovative recycling processes. Both types are considered especially from the perspectives of institutional obstacles and feedback mechanisms aimed at overcoming the obstacles.

The key result of this study is a theoretical presentation of the structure and functioning of an institutional feedback mechanism. To function in a complex operational environment, an institutional feedback mechanism should consist of two components: the production of the right kind of knowledge (*knowledge networking*) and the management and maintenance of a network of actors that are central to the specific aims (*network governance*). This dissertation shows different ways to identify, conceptualize, and study these two components of institutional feedback mechanisms. By means of an example, the study also demonstrates how an institutional feedback mechanism can be constructed and how it can be utilized to overcome practical problems and profound institutional obstacles. Policy recommendations for the management of complex operational environments and for the promotion of a circular economy and material efficiency are also presented.

TIIVISTELMÄ

Kiertotalous on ajankohtainen aihe yhteiskuntapolitiikassa sekä yhteiskuntatieteellisessä ympäristötutkimuksessa. Tässä väitöskirjassa tarkastellaan kriittisesti kiertotalouden kehittämiseen ja teollisuudessa tapahtuvan materiaalien kierrättämisen edistämiseen tähtääviä toimenpiteitä. Työssä tunnistetaan sellaisia tekijöitä, jotka estävät tai hidastavat teollisen kierrätyksen kehittämistä sekä etsitään uudenlaisia ratkaisuja näiden esteiden ylittämiseksi.

Työn keskiössä ovat institutionaaliset esteet, jotka määritellään toisaalta muodollisiksi esteiksi eli esimerkiksi lainsäädännöstä johtuviksi hallinnollisiksi ongelmiksi ja toisaalta epämuodollisiksi esteiksi eli esimerkiksi vakiintuneista rutiineista ja toimintatavoista johtuviksi. Perinteisen tulkinnan mukaan institutionaaliset esteet ovat ensisijaisesti joko muodollisia tai epämuodollisia. Tämä työ haastaa perinteisen tulkinnan ja väittää, että usein vaikeimmat esteet ovat sellaisia, jotka operoivat muodollisten ja epämuodollisten esteiden välimaastossa. Välimaastossa toimiminen katkaisee yhteyden muodollisen hallinnon todellisuuden ja epämuodollisen operatiivisen todellisuuden välillä. Muodollinen ja epämuodollinen todellisuus ovat kuitenkin rakenteellisesti riippuvaisia toisistaan ja tämän vuoksi sääntöjärjestelmien tai epämuodollisten toimintatapojen asianmukainen kehittäminen on vähintäänkin haastavaa ellei mahdotonta tilanteessa, jossa yhteys todellisuuksien välillä on katkennut.

Samaan aikaan väitöskirja osoittaa, että sen jälkeen kun katkennut yhteys muodollisen ja epämuodollisen todellisuuden välillä on tunnistettu, on myös mahdollista luoda uusi yhteys. Uuden yhteyden luominen voi tapahtua olosuhteisiin soveltuvan institutionaalisen palautemekanismin avulla. Institutionaalinen palaute tarkoittaa tiedonvaihdon ylläpitoa eri todellisuuksissa toimivien ihmisten ja ihmisryhmien välillä. Teollisuuden kontekstissa institutionaalinen palaute voi esimerkiksi mahdollistaa uudenlaisten kierrätystapojen kehittämisen sekä materiaalien hyödyntämiskäytäntöjen jatkuvan tehostamisen. Innovatiivisella tavalla rakennetut institutionaaliset palautemekanismit voivat tarjota uudenlaisia mahdollisuuksia niiden esteiden ylittämiseen, joita materiaalien kierrättämisen kehittäminen ja kiertotalouden edistäminen jatkuvasti kohtaavat yhteiskunnan eri aloilla.

Väitöskirja koostuu neljästä tapaustutkimuksesta, jotka tarkastelevat teollisuudessa käytettävien materiaalien ja muiden resurssien hallintaa raskaan teollisuuden yksiköissä Perämerenkaaren alueella Pohjois-Suomessa. Käsitellyt teollisuusyksiköt kattavat suomalaisen perusteollisuuden perinteiset alat: metalli-, puunkäsittely- ja kemianteollisuuden. Työn pääasiallinen aineisto koostuu

haastattelumateriaaleista, kyselytutkimuksista sekä dokumenttiaineistoista. Työssä ollaan erityisesti kiinnostuneita kahdenlaisesta kierrätystavasta: 1) erilaisten ylijäämämateriaalien hyödyntämisestä olemassa olevien tuotteiden korvaajina tai uusien tuotteiden raaka-aineina sekä 2) täysin uudenlaisten kierrätystuotteiden ja innovatiivisten kierrätysprosessien kehittämisestä. Kumpaakin näistä kierrätystavoista tarkastellaan erityisesti institutionaalisten esteiden ja niiden ratkaisemiseen tähtäävien palautemekanismissien näkökulmista.

Työn keskeisin tulos on teoreettisesti jäsennelty esitys institutionaalisen palautemekanismin rakenteesta ja toiminnasta raskaan teollisuuden kontekstissa. Voidakseen toimia kompleksisessa toimintaympäristössä, institutionaalisen palautemekanismin tulee koostua kahdesta komponentista: oikeanlaisen tiedon yhteisöllisestä tuottamisesta (engl. *knowledge networking*) sekä tavoitteiden kannalta keskeisten toimijoiden verkoston hallinnasta (engl. *network governance*). Työssä esitetään erilaisia tapoja näiden kahden komponentin tunnistamiseen, käsitteellistämiseen sekä tutkimiseen. Esimerkin avulla havainnollistetaan myös sitä, kuinka institutionaalinen palautemekanismi voidaan luoda ja kuinka sen avulla voidaan ratkaista käytännöllisiä ongelmia sekä ylittää syvällisempiä institutionaalisia esteitä. Työssä esitetään myös politiikkatoimenpiteitä kompleksisten toimintaympäristöjen hallinnan kehittämiseen sekä konkreettisia suosituksia kiertotalouden ja materiaalitehokkuuden edistämiseen.

PREFACE

Writing a doctoral dissertation includes many unexpected episodes, events, and activities. The writing process takes place over different periods of time, each of which involves different people. I would like to take this opportunity to acknowledge the persons who have contributed to this project.

I would like to begin by thanking my supervisor, Professor Janne Hukkinen, who guided me first through a master's thesis and then encouraged me to pursue a Ph.D. During my doctoral studies, Janne has continuously provided gentle advice on all kinds of confusing issues that I have confronted along the way. Most important, Janne has offered his strict, yet inspiring and constructive criticism at every stage of my work. Our (sometimes very long-lasting) discussions have laid the groundwork for my own scientific thinking and writing. I would like to thank Janne for his commitment, trust, and patience.

I began my research on this dissertation in a project entitled *Pro-Environmental Product Planning in a Dynamic Operational Environment Now and in the Future: Methods and Tools* (ProDOE), sponsored by the Academy of Finland. The consortium for the project included individuals who became very important to the entire process. I would especially like to thank Professors Olli Salmi and Kari Heiskanen and the researchers Sanni Eloneva, Nani Pajunen and Mikko Mäkelä for their rewarding collaboration during and after the ProDOE. Olli, Nani, and Sanni also helped in the data collection and other practical arrangements, such as organizing various events and workshops that were crucial to my research. I am very grateful for that. Sanni and I also co-authored one of the research articles; I must say that, for me, this was the most pleasant writing experience of all of my articles.

After the ProDOE project, I enrolled in the Finnish Graduate School in Environmental Social Science (YHTYMÄ). I would like to thank all of my fellow students for our inspiring discussions in the seminars in Tampere. I would especially like to thank the director of the school, Professor Yrjö Haila, for his kind advice and encouragement in the critical stages of my work. Other important figures, especially in the final stage of the dissertation, were Professors Jouni Paavola and Juha Hiedanpää, who served as pre-examiners. Their insightful comments helped improve the synthesis section substantially. In addition, I would like to express my great gratitude to Jouni for acting as my opponent in the doctoral defense.

I was fortunate to have the opportunity to write my dissertation on the third floor of Snellmaninkatu 10, where various soul mates were conducting similar projects with similar challenges and were experiencing moments of despair and joys of success similar to mine. I would like to thank Sanna Ahonen, Annukka Berg, Kevin Drain, Sami Heikkilä, Maria Heiskanen, Tuuli

Hirvilammi, Nina Honkela, Katri Huutoniemi, Mika Hyötyläinen, Anna-Maria Isola, Jan Johansson, Nina Kahma, Hanna Kara, Farid Karimi, Frateline Kashaga, Jussi Kulonpalo, Tanja Kuronen, Senja Laakso, Jyri Liukko, Riikka Lämsä, Karoliina Majamaa, Johan Munck af Rosenschöld, Liisa Mäkinen, Anne Määttä, Elina Pekkarinen, Semi Purhonen, Paula Saikkonen, Paula Schönach, Sarianne Tikkanen, Arho Toikka, Tiina Valkendorff and Antto Vihma for refreshing company, peer support and excellent discussions.

Three different groups have been very important to my work. First, the Environmental Policy Research Group (EPRG) has been my academic home, and I am grateful to all of its members and visitors to the group for their ability to create a warm and appreciative atmosphere for our research sessions. I have learned so much from each of you. The research seminar on environmental policy has been my second source of inspiration and support, and I thank all of its participants as well as the organizing chairs, Janne Hukkinen and Eeva Berglund. Third, I have been deeply involved in the Finnish Society for Environmental Science (YHYS ry). I very much appreciate all of the fellow board members and other active people who have devoted their time to organizing events and other activities for the society. These activities have given me numerous fresh ideas.

During my doctoral studies, I also had an opportunity to spend an academic year (2012-13) as a visiting researcher in the School of Public Affairs at the University of Colorado Denver. My humble thanks goes to Professor Tanya Heikkila for serving as my academic advisor during the visit. Tanya's passion for the work in progress and her continuous encouragement of fellow researchers is something that I have not encountered anywhere in academia. It was an honor for me to participate in the Workshop on Policy Process Research (WOPPR), which she led along with Professor Christopher Weible. I am equally grateful to my fellow Ph.D. students and their spouses, post-docs, and assistant professors, especially David Carter and Sarah Shepherd, Samuel and Laura Gallaher, Todd Ely, Mark Davis and Jon Pierce. The heartfelt friendship of my U.S. colleagues and their families made the exchange an unforgettable experience for my wife and me. Additionally, I would like to thank Mr. Scott Steinbrecher for his help in practical arrangements in the U.S. and the Fulbright program for economic support.

Without a family and close friends a poor Ph.D. student would probably lose his connection to reality and become lost on an imaginary planet called *Science*. I am especially grateful to Juha Tuomainen, Arto Kortelainen and Mikko Juvonen for their awesome company in our running and skiing travels, training sessions, hiking trips, weekly café get-togethers, and occasional sauna evenings. I also wish to thank the captain of S/y Astrea, Ari Serkkola, for proving endless opportunities for oceanic adventures in the Baltic Sea. Maija Jäppinen went through her Ph.D. pipeline at almost at the same time as I, and I believe that we succeeded rather well in supporting each other. For that, I thank Maija and her beloved daughter, Iris Ilona.

During the last few years, *Avoim taidekoulu* (the Open Art School) has been a powerful balancing element between my research work and other interests, and for that reason I owe my sincere gratitude to my friends there.

I give my warmest thanks to my family. My parents, Merja and Hannu Levänen, have supported me at every stage of my long-lasting studies. Even more importantly, they have always understood my thoughts and encouraged me to go in the directions that I have experienced as meaningful in life – I cannot be grateful enough for that. My sister, Heidi Purola, and her husband Jukka Purola have provided help and support whenever needed, and I am grateful to them as well.

Finally, my greatest thanks goes to my wife, Pinja Nieminen, for all the love, wisdom, and never-ending encouragement that you keep providing me. I have been so privileged to share this journey, and my life, with you. I dedicate this work to the future of our family.

Espoo, August 2015

Jarkko Levänen

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LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following publications:

I Levänen, Jarkko, and Eloneva, Sanni. Submitted. Comparing options for carbon capture and storage: Environmental and institutional perspectives. (Under review for publication in *Journal of Industrial Ecology*.)

II Levänen, Jarkko, and Hukkinen, Janne. 2013. A methodology for facilitating the feedback between mental models and institutional change in industrial ecosystem governance: A waste management case-study from northern Finland. *Ecological Economics*, vol. 87, pp. 15-23.

III Levänen, Jarkko. 2014. Policy deliberation and the trading zone metaphor: Evaluating expert participation in the reform of Finnish waste policy. *Environmental Policy and Governance*, vol. 24(5), pp. 364-376.

IV Levänen, Jarkko. 2015. Ending waste by law: Institutions and collective learning in the development of industrial recycling in Finland. *Journal of Cleaner Production*, vol. 87, pp. 542-549.

The publications are referred to by their roman numerals.

Author's contribution in co-authored articles

Article I was co-authored with Sanni Eloneva. The author of this thesis had the main responsibility for planning and writing the article and he also conducted the analysis of the “conventional CCS application.” Eloneva was responsible for the analyses of the “emerging CCS applications.” Both authors contributed equally to the formulation of the results and conclusions.

Article II was co-authored with Janne Hukkinen. The author of this thesis had the main responsibility for planning and writing the article and conducting the analyses. Hukkinen contributed significantly to the development of the analytical framework, the clarification of the results, and the formulation of the conclusions.

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1 INTRODUCTION

“Our enormously productive economy demands that we make consumption our way of life, that we convert the buying and use of goods into rituals, that we seek our spiritual satisfaction, our ego satisfaction, in consumption ... We need things consumed, burned up, worn out, replaced, and discarded at an ever increasing pace.” (Lebow, 1955, 7).

In the quotation above, Victor Lebow describes an attitude to consumption that can be characterized as “from use to disposal”. The intensified transformation of commodities from use to disposal is the driver of progress in our dominant, neoclassical economic system. In this system, added value is the consequence of efficient exploitation of seemingly infinite resources. The neoclassical economic system has developed gradually over the last few centuries to the point that its principles permeate all sectors of Western societies (e.g., Harvey, 2007). This development is not surprising, because until recent decades, the availability and reasonable price of almost all major natural resources have seemed to be guaranteed. Today, however, we are waking up to the realization that depletion of natural resources together with other large-scale environmental threats, such as climate change and biodiversity loss, signal an urgent need for rethinking the roles of consumption practices, economics and the production systems in our societies (European Commission, 2014; IPCC, 2014; The Worldwatch Institute, 2013).

In this dissertation, I evaluate ways of overcoming institutional obstacles to industrial recycling. Increased industrial recycling of materials and other resources is among the most important prerequisites in the search for more sustainable production systems because industries generate very large amounts of reusable residual materials and other resources. The general understanding of institutional obstacles is that they are only related to administrative rule systems manifested in laws and regulations. I approach institutional obstacles from a wider perspective and argue that, in fact, an institutional obstacle means a mismatch between formal rules and informal ways of doing things. Institutional obstacles disconnect formal institutional reality from the informal operational-level reality and thus hamper the implementation of both legal and practical changes. I will also argue that it is possible to reunite formal and informal realities by means of appropriately functioning institutional feedback mechanisms. Such a mechanism offers a way to overcome the institutional obstacle. Institutional obstacles and institutional feedback mechanisms in the context of heavy industries are the two main topics of this dissertation.

1.1 BACKGROUND: TOWARD A CIRCULAR ECONOMY

Circular economy is a term that constantly crops up, in one form or another, from newspaper articles to high-level governmental strategies. A circular economy takes a critical stance on the “from use to disposal” thinking and can therefore be seen as an alternative model for the dominant economic system (e.g., Ellen MacArthur Foundation, 2014). The basic premise of a circular economy is that resources are not abundant. From this it follows that economics cannot rest on the continuous intensification of the exploitation of resources, but instead, added value must be created from the circulation of materials and other resources. The key insight of a circular economy, namely, that the economy cannot be seen as a phenomenon separate from the biophysical reality, is an imperative that should direct the design of those institutions which determine the selection of alternative future paths for societies. At the same time, it is important to ensure that intensified recycling does not lead to intensified use of energy, which tends to translate into intensified use of resources. I argue that it is difficult to implement the principles of a circular economy through the existing institutional setting because existing institutions have mainly been built on a belief system that reflects “from use to disposal” thinking.

A circular economy can be considered a new belief system that challenges “from use to disposal” thinking. How can we change our institutional setting so that it gradually begins to reflect the principles of a circular economy? My argument is that such a change can only take place if it is implemented through a dialogical process between formal and informal institutional realities. Even though both authorities and industrial actors would agree that the circular economy is a vision worth pursuing, patient work is still needed to change formal and informal institutions one by one. I will point out that the obstacles to institutional change are usually rather simple, albeit powerful, and they can hamper the modification of large sets of institutions in particular fields. The aim of this dissertation is to show that it is possible to dismantle these obstacles by means of institutional feedback mechanisms. In this sense, my work offers practical tools for considering a circular economy in an industrial context.

1.2 INDUSTRIAL ECOLOGY

Another key concept for my work is *industrial ecology*. Industrial ecology is a planning theory that evaluates ways of reorganizing the production system within societies (e.g., Lifset, 2009). The basic idea in industrial ecology is to imitate natural systems in industrial planning (Frosch and Gallopoulos, 1989). Industrial ecology conceptualizes industrial networks as “symbioses” or “ecosystems” among which residual materials and other resources, such as energy and knowledge, are utilized in novel ways (e.g., Ayres, 2002; Graedel

and Allenby, 2010). I adopt the perspective of industrial ecology on industrial recycling. Thus, in this dissertation industrial recycling does not mean only the reuse of leftover materials. The concept of industrial ecology helps us to consider and define the role of industrial recycling in different contexts. As will be pointed out in the sections below, industrial recycling can mean, for example, intelligent utilization of challenging residuals, such as carbon dioxide (CO₂) emissions or the development of completely new kinds of product concepts. Case-specific conceptions of industrial ecology may also offer possibilities for different win-win situations. For example, by means of certain novel carbonation technologies, it is possible to decrease the CO₂ emissions and simultaneously increase the material efficiency of an industrial unit.

Industrial ecology is also a good example of a rather controversial model of production (see van Den Bergh and Janssen, 2004). For many of us, it is reasonable to defend the general aims of industrial ecology, since they can be associated with other favorable developments such as improved environmental protection as well as general safety and well-being. However, it may also seem reasonable to agree, to some extent, with the criticism of the limited capability of industrial ecology to function as a wide-ranging planning model. The reason may be that, ontologically, we consider industrial ecology “only as a sub-system model,” which is disconnected from our institutional reality. Perhaps partly unconsciously, we miss identifying a broader model that would clearly pinpoint the inabilities of the current economic system and related institutions to address those environmental challenges that we consider direct threats to our current living conditions. At first glance, we may not see that our own overconsumption and its mirror image, global overproduction, may be among those direct threats.

The reason for raising this issue is that models are strong shapers of our thinking. We assimilate numerous issues in models such as industrial ecology and the circular economy. The implications of industries on our lives, for example, are profound: industries create and destroy livelihoods, mold our living environments, shape our behavior through marketing, and affect consideration of policies. Therefore, when we think of industrial ecology, we actually think simultaneously of our everyday living and the future prospects for our lifestyle. If the model does not properly integrate “our things” with other conceptualized aspects, we may consider it inadequate. In a similar manner, industrial ecology divides expert opinion. Advocates see numerous connections between the principles of industrial ecology and the basic premises of their own professional thinking. That is why they consider industrial ecology a solution for almost all industry-related problems. Critics, on the other hand, do not conceive such connections and are therefore apt to consider industrial ecology an unrealistic intellectual exercise. (Boons and Howard-Grenville, 2009).

The division of opinions, however, does not result from the failures of the models. Actually, the fact that conceptual models influence our thinking

about reality is precisely what makes them valuable. Properly outlined models force us to think carefully about the complex relationships among the profound systems in societies. Good examples of such systems are the foundations of our institutional settings and economic models. Focused thinking lays the groundwork for the improvement of policies and practices related to modeled systems. If the aim is to change systems, then models with normative goals can reveal important shortcomings of a current system. Industrial ecology, for example, initiates reflection on the connections between institutions, production systems, and economics. At the same time, in its prescriptive dimension, industrial ecology is a model that aims ultimately to enhance the circulation of materials and other resources (Ehrenfeld, 2004; Lifset, 2009). A similar normative goal underlies a circular economy, and in this sense, industrial ecology can be considered an application of a circular economy in an industrial context. Both of these concepts are valuable in the consideration of the potential and the challenges of industrial recycling in different situations.

1.3 INSTITUTIONS IN INDUSTRIAL RECYCLING

I observe industrial recycling from an institutional perspective, which means that I explicate how different, formally defined rule systems (formal institutions) together with established ways of doing things (informal institutions) influence the emergence of industrial recycling within and between industrial companies. The reason for this perspective is that many obstacles to industrial recycling originate in institutional problems (e.g. Ehrenfeld, 2004). This may appear surprising to those who assume that the market mechanism is the factor which either enables or prevents the reuse of residual materials in an industrial context – a reasonable assumption, as markets determine almost all aspects of material management. We should not forget, however, that the market mechanism also operates in the institutional context. Collectively accepted rules, in the end, define how markets function.

I will portray industrial recycling as a multi-dimensional phenomenon. Even though I focus on institutional factors, I try to avoid underrating the significance of numerous other factors affecting the progress of industrial recycling. Different perspectives on the same issue should be complementary rather than exclusive. Consider the above-mentioned market mechanism as an example. While preparing this dissertation, I gradually realized that if a representative of an industrial company is asked why a particular leftover material remains unused, the answer very likely reflects, in one way or another, the cost-effectiveness of recycling. Is this observation inconsistent with my earlier notion that the problems of industrial recycling are primarily institutional? The answer is: yes and no. In truth, it is often unprofitable for companies to launch new recycling processes or to transport residuals to re-

use locations far away. At the same time, it is also possible to influence the profitability of recycling because institutions define the rules for the residual markets. Institutions and the market mechanism always function in relation to each other, and often the apparent problems of industrial recycling are actually visible signs of deeper institutional obstacles. This dissertation offers tools for identifying and working on these more profound obstacles.

The starting point for the dissertation was the notion that informal ways of doing things and the formal rule systems do not operate or evolve in isolation from each other, but instead, formal and informal realities are connected by case-specific feedback mechanisms. The profound meaning of these mechanisms has been recognized in the theoretically oriented literature (e.g., Ostrom, 1990; 2005; North, 1990, 2005), but their working logic has not been fully understood. Moreover, there is a lack of empirical case studies demonstrating the structure and other features of institutional feedback. I argue that institutional feedback mechanisms are powerful forces driving industrial recycling. The emergence of industrial recycling consists of a series of insights that deal with the utilization opportunities of residual materials and other resources. These insights turn into practices if they prove technically and economically feasible and compatible with the formal rule systems of industries. Generally, the implementation of new ideas requires a modification of the rule systems and/or the conventional ways of doing things. In other words, the institutionalization of industrial recycling requires institutional changes, and that is when feedback comes into play. If the formal and informal rule systems can be modified so that they support the materialization of new ideas, then the opportunities for the development of industrial recycling rise exponentially.

1.3.1 A GAP IN THE LITERATURE ON INSTITUTIONAL DYNAMICS

What does the above-mentioned gap in the institutional literature on feedback mechanisms mean in practice? The first issue is that institutional feedback and other similar phenomena have been discussed in various fields of social sciences and economics (e.g., Jordan, 2010; Ostrom, 2005; North, 2005; Velázquez Gomar 2014; Young, 2002, just to mention a few). The problem, however, is that in diverse scholarly discussions, feedback or its neighboring concepts have been used in divergent ways, creating terminological confusion. The majority of authors who deal with these phenomena in a way more or less similar to my approach, do not use the term “institutional feedback.” Nor do they discuss the concept in details or define precisely their position related to it. This creates a gap: a phenomenon has been recognized, yet there is no established terminology for approaching it analytically. My argument is that environmental social science, as well as social sciences and economics in general, would benefit from a mutually agreed-upon definition of institutional feedback, and therefore one aim of

this dissertation is to produce such a definition. I will return to this issue in *Analytical framework* section.

In this dissertation, I will shed light on the institutional obstacles operating behind the ordinary and better-known problems of recycling. The empirical portion consists of four case studies, which focus on institutional obstacles dealing with formal definitions of materials and technologies. My work helps the reader think about and identify other kinds of institutional obstacles in different contexts. My work also helps in the consideration of ways to overcome those obstacles. The goal is to point out that, in many cases, it is possible to develop institutional feedback mechanisms that solve problems dealing with malfunctioning knowledge exchange between formal and informal realities. That issue has not been addressed in detail in the existing literature on institutional dynamics. The present study is likely to be helpful in different situations, because institutional obstacles usually resemble each other in one way or another. At the same time, I suggest keeping in mind that, even though overcoming institutional obstacles may appear to be a series of single solutions, each measure taken is itself an important building block in new kinds of production systems, which affect the evolution of economics. Through institutional changes, we can end the reproduction of such societal arrangements that do not properly reflect our thinking.

1.4 RESEARCH QUESTIONS

The emergence of industrial recycling can be seen as an institutionalization process (Cohen and Howard, 2006; Boons and Howard-Grenville, 2009). Industrial recycling increases when the formal regulations and incentives that guide industrial operations evolve in a dialogical manner with the actors' informal ways of doing things. A dialogical process is crucial because it is impossible for a single actor, or a group of actors who share a similar perspective, to conceive all relevant functions of a multi-dimensional industrial system or its links to other societal systems. The research goal of this dissertation is to evaluate ways of overcoming the institutional obstacles that hamper the dialogical process among the stakeholders of industrial recycling and thereby prevent or delay the desired developments toward improved material management. To achieve this goal, I have posed the following research questions:

1. *How do institutional obstacles hamper the development of industrial recycling?*
2. *How does institutional feedback function in an industrial operational environment?*
3. *What is the role of institutional feedback in overcoming institutional obstacles?*

Below I briefly summarize how the four research articles contribute to answering these questions.

The first article, *Comparing options for carbon capture and storage: Environmental and institutional perspectives on mineralization*, was co-authored with Sanni Eloneva. The article introduces a typical institutional obstacle, which in this case is an outgrowth of an insufficient legal definition of a certain technology. In the article, we demonstrate the potential of emerging carbon capture and storage (CCS) technologies, which are capable of storing carbon dioxide in novel locations, such as industrial residual materials. Legislation by the European Union (EU), however, does not consider emerging technologies as “CCS methods.” The formal terminology related to CCS segregates emerging CCS technologies from the policy regime related to CCS, and thus the incentives aimed at encouraging the use of CCS do not apply to the emerging technologies. This example shows how one formal definition can function as a significant institutional obstacle.

The second article, *A methodology for facilitating the feedback between mental models and institutional change in industrial ecosystem governance: A waste management case-study from northern Finland*, was co-authored with Janne Hukkinen. This article demonstrates stakeholders’ various mental models related to institutional obstacles. Here we present a methodology for identifying institutional obstacles and for studying different functions of informal institutional feedback mechanisms. We also introduce a means of organizing an institutional feedback process among the stakeholders in industrial recycling in Finland. The article demonstrates how different stakeholder groups anticipate changing waste legislation and points out how the authorities would implement new legislation in the absence of institutional feedback.

In the third article, *Policy deliberation and the trading zone metaphor: Evaluating expert participation in the reform of Finnish waste policy*, I study situation in which experts from different organizations try to construct a formal feedback mechanism during the preparation of new waste legislation. Experts involved in the preparation are expected to solve policy-related problems simultaneously with the promotion of diverse interests, which makes the situation challenging. I describe how political tensions among the interest groups affect the work of experts and the outcomes of the process. The results of the article highlight differences between formally launched working groups and a more informal one: formal groups were less competent in the generation of new ideas than the informal group. The framework for the analysis is built around the trading zone metaphor first introduced by Peter Galison (1997).

In the fourth article, *Ending waste by law: institutions and collective learning in the development of industrial recycling in Finland*, I describe how an institutional feedback mechanism functions in practice and I also present concrete examples of the feedback processes. The studied institutional feedback mechanism is by-product criteria, introduced in renewed Finnish waste legislation. The criteria affect the commercialization of industrial by-products in different ways. In the article, I explicate the ways in which an institutional feedback mechanism affects collective learning among the developers of innovative by-product concepts. The article points out that by-product criteria promote the utilization of existing knowledge about the materials, but these criteria fail to facilitate collective learning related to the development of new by-products.

2 ANALYTICAL FRAMEWORK

In the *Introduction*, I outlined the thematic connections among institutions, industrial ecology, and the circular economy. I will return to those connections every once in a while, but for now they will be left in the background while I introduce the analytical framework for the dissertation. This framework is comprised of elements from the theories I have adopted in the four research articles. A detailed introduction of theories and concepts is given in the articles, while in this section I illustrate the relationships among the concepts and describe how they contribute to the dissertation. The framework thus developed enables a combined analysis of various functions of institutional obstacles, institutional feedback, and institutional change. This section will also help the reader understand the methodological choices made in the research articles.

2.1 INSTITUTIONS, OBSTACLES, AND FEEDBACKS

Industrial manufacturing and its development take place in the interplay between formal rules and informal ways of doing things (*Articles II and IV*). The aim of this dissertation is to ascertain the details of key functions of this interplay. I will focus on the institutional obstacles that hamper the interplay and the feedback mechanisms that may strengthen the interplay. I will begin this endeavor with a definition of key concepts in the analytical framework: *institution*, *institutional change*, *institutional obstacle*, and *institutional feedback*.

- *Institution*. In this dissertation institutions are defined as *rules*. Douglass North has provided the most famous crystallization of this idea: “[i]nstitutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction” (North, 1990, 3). This definition captures the essential notion of institutions as rules, while at the same time it does not delimit the types of rules that can be conceptualized as institutions. Specific institutions always reflect particular mental models, which in turn reflect wider belief systems. In this dissertation, the “game” in North’s terminology refers to the management of an industrial manufacturing system, with key categories of institutions being *formal institutions* and *informal institutions*. Formal institutions consist of formal rules that are codified in laws and lower-level regulations, as well as authorities’ officially stated (e.g. instructed) interpretations of those rules. Informal institutions consist of other stakeholders’ informal rules

and their interpretations of those rules. By “other stakeholders,” I mean industrial actors and representatives of different interest groups; by “informal rules,” I am referring to actors’ norms, practices and routines related to industrial material management. (*Article II*).

- *Institutional change*. Overall institutional change related to a certain phenomenon consists of smaller changes in formal and informal institutions dealing with that phenomenon. Overall institutional change is fashioned in the interplay between formal and informal institutions, and therefore, successful interplay between these institutional realities can accelerate the overall institutional change. In the context of this dissertation, overall institutional change means the institutionalization process of industrial recycling. In other words, overall institutional change refers to a series of changes in both formal and informal institutions that holds the potential to promote industrial recycling.
- *Institutional obstacle*. By institutional obstacle, I mean any feature of formal or informal institutions that in some way delays or prevents the process of institutional change. Because institutions are defined as rules, an institutional obstacle is a quality of a rule that hampers or prevents actions favorable to the promotion of industrial recycling. An institutional obstacle jeopardizes the development of practices or formal rules that would be more appropriate to the situation at hand. Institutional obstacles can also be seen as a mismatch between a regulation and the actors’ informal ways of doing things. Insufficient formal definitions of critical issues that prevent favorable actions in certain operational environments are good examples of institutional obstacles.
- *Institutional feedback*. By its ontological nature, institutional feedback is one of the key processes in all human interactions. In this dissertation, institutional feedback is defined as maintenance of knowledge exchange between formal and informal institutions. Institutional feedback consists of two components: network governance and knowledge networking. These components will be introduced in this section. The purpose of the institutional feedback process is to facilitate and maintain a network in which actors can engage in collective knowledge production. Appropriately functioning institutional feedback launches a dialogical process that builds bridges between actors and actor groups operating in formal and informal institutional realities. Institutional feedback can also be considered a coordination

process between two institutional realities. Coordination reinforces the interplay between actors and thus accelerates change in both realities, which in turn contribute to overall institutional change.

2.2 THE LOGIC OF INSTITUTIONAL OBSTACLES

It is rather straightforward thinking to believe that nuances in formal regulations can sometimes constitute lock-in situations, which in turn can lead to unfavorable consequences. For example, during the research for this dissertation, I have learned that in certain circumstances, particular details of waste legislation may prevent the reasonable reuse of some residual materials in industrial companies (*Articles II and IV*). Similar unfavorable functions are found in the informal ways of doing things. *Article I*, for example, describes a situation in which the particular scientific practices of experts in the EU marginalize some of the emerging methods for carbon capture and storage (CCS). This kind of behavior simultaneously reinforces a policy regime's built-in inability to support the development of emerging CCS technologies. These examples illustrate how obstacles to the institutionalization process of industrial recycling can originate either in the qualities of formal or informal institutions (see also North 1990; *Article IV*).

Despite their origin, however, the functioning of institutional obstacles typically takes place between the formal and the informal institutional realities, and this is the main issue that makes overcoming institutional obstacles such a challenging task (*Articles I and IV*). In the forthcoming sections, I introduce some institutional obstacles that originate in the formal definitions of materials or technologies. The common denominator among these obstacles is that they operate in the interplay between formal and informal institutions (*Article IV*). For the same reason, attempts to overcome these institutional obstacles cannot be based on solutions that concentrate solely on the qualities of formal or informal institutions. The success of individual solutions depends on their capacity to interlink these two realities in a functional way.

A systematic evaluation of institutional obstacles requires patience from an analyst. The first impression may be that obstacles are pervasive and complex, and when an analyst tries to grasp those, they may seem to disappear and lurk somewhere in the background until they resurface again in a new context. Luckily, however, there are conceptual tools that help in approaching institutional obstacles analytically. *Article II* introduces a methodology for conceiving the dynamics between formal and informal institutional realities and – as part of the methodology – a way to begin identifying institutional obstacles in the context of industrial manufacturing. The methodology is based on *action theory*, originally introduced by Alexei Leontév, Alexander Luria, and Lev Vygotsky (see, e.g., Leontév, 1978; Luria, 1976; Vygotsky, 1978, 1981). In the identification of institutional obstacles,

the *activity system model*, which can be considered an outgrowth of the initial action theory, is particularly useful (see, e.g., Engeström 1999, 2010). The basic elements of the activity system model are illustrated in Figure 1.

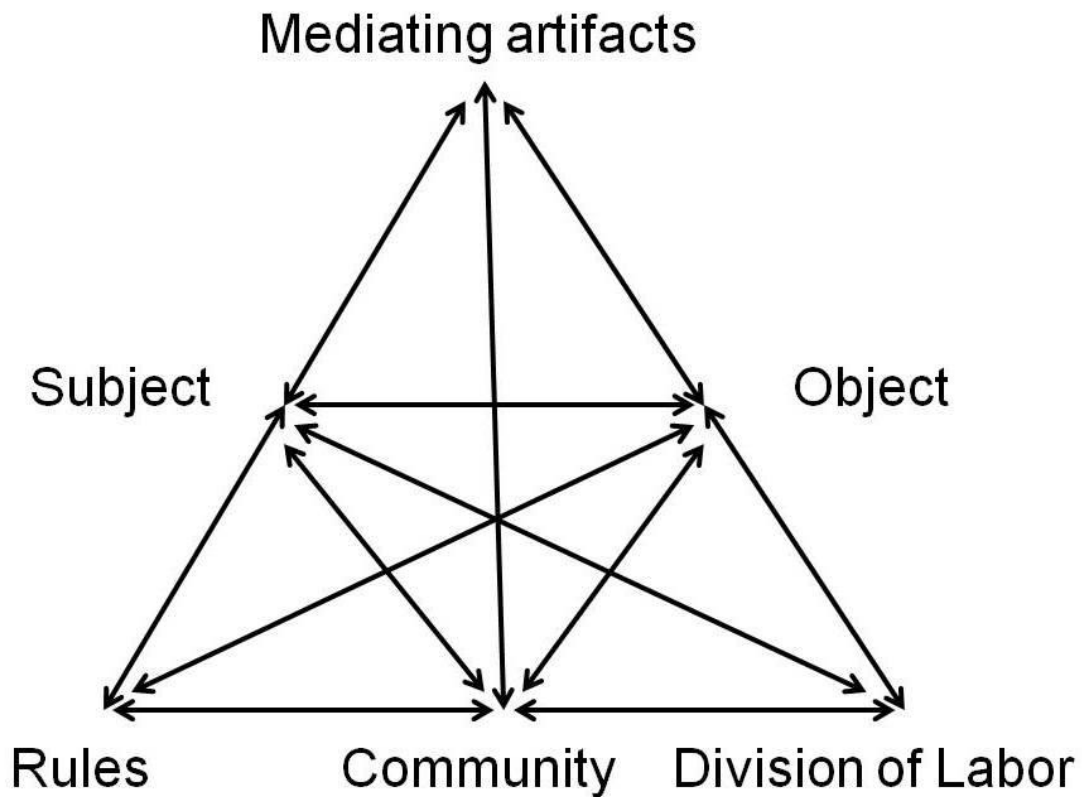


Figure 1. *The basic elements of the activity system model* (adapted from Engeström, 1999, 29-36).

The activity system model helps an analyst outline the key elements within formal and informal institutional dimensions based on the phenomenon being analyzed. Once the key elements have been identified, it is easier to evaluate their reciprocal relationships and the linkages to other systems. It is important, however, to recognize that the activity system model only helps clarify a situation; it does not offer ready-made answers for identifying institutional obstacles. For example, in *Article II* we adapt the activity system model to identify the conflicting elements in the mental models of different stakeholders in industrial recycling. Still, the identification of conflicting elements does not mean that any of them will turn out to be an institutional obstacle. The identification of conflicting elements needs to be seen as an organized attempt to clarify the field of problems related to a particular phenomenon. Such clarification guides an analyst further and may also offer valuable hints about institutional obstacles, but it does not point them out. Identification of institutional obstacles requires in-depth understanding of both regulatory and operational environments. In practice, the institutional

analyst can utilize different methodologies to gain such understanding, as demonstrated in *Articles I-IV*.

2.3 INSTITUTIONAL FEEDBACK AS A UNIT OF ANALYSIS

Once the institutional obstacle related to a particular phenomenon has been identified, analyst can proceed further and start to think about different strategies for overcoming the obstacle. The main argument of this dissertation is that construction of institutional feedback mechanism may be appropriate strategy for tackling the problems generated by the institutional obstacle. Next, I will briefly describe how institutional feedback and some of its neighboring concepts have been discussed in the existing institutional theory. After that, I am ready to go forward and describe 1) how the institutional feedback works and how it contributes to institutional change, 2) what is the structure of institutional feedback mechanism, and 3) how different functions of institutional feedback can be studied. The exploration of these three issues is important because in the forthcoming sections I will argue that institutional feedback is the key process in overcoming the institutional obstacles of industrial recycling.

2.3.1 THE EXISTING LITERATURE

In the *Introduction* I stated that institutional feedback has been discussed in various fields of the social sciences and economics, but the majority of authors do not in fact use the term “institutional feedback.” I must begin my review of the existing literature by mentioning that, in some situations, the term “institutional feedback” has been used successfully. In the field of political science, there are studies of institutional feedback processes between diverse health care institutions and public opinion in support of national health care (e.g., Edlund, 2007; Jordan, 2010). In an analytic sense, these studies come close to my approach to institutional feedback, as they set out to identify the dynamics between the features of specific institutions and wider belief systems. Still, comparisons between these studies and my approach remain somewhat imprecise, because in political science or in other fields of the social sciences and economics there is no univocal definition for institutional feedback, which is why authors who use the term define it differently in different contexts.

Another problem in the conceptualization of institutional feedback is that the numerous, partly overlapping concepts share similarities with institutional feedback, yet describe somewhat different phenomena. According to the present study, *institutional interaction* and the *interplay* between institutions are the most important examples of these concepts.

Institutional interaction, as discussed, for instance, by Sebastian Oberthür (2009) and José Velázquez Gomar (2014), refers to a process that promotes the policy integration of multilateral agreements. In this stream of discussion, interaction is expected to bring about synergies, but it may also lead to new kinds of problems. Interplay between institutions, as discussed especially by Oran Young (e.g., 2002; 2008), refers to a similar type of interaction between environmental regimes in both vertical and horizontal dimensions. By using the terminology of interplay, it is possible to investigate how well institutional regimes at different layers of multi-level governance (the vertical dimension) or separate regimes in the same layer (the horizontal dimension) *fit* together or with biophysical systems. If regimes fit together well, then interplay increases, which is expected to increase the competence of the governance system. Overlapping between these concepts is evident because the literature of institutional interaction emphasizes the management of interplay in the search for policy integration, and vice versa: the literature on interplay stresses the need for interaction among actors associated with different regimes.

How then does institutional feedback differ from interaction and interplay? And why do we need a clear-cut definition for it? As discussed above, in the existing literature, institutional interaction is a prerequisite for favorable policy integration, while interplay is a feature of a competent and flexible governance system. The literature on these topics, however, does not outline a clear link or make a distinction between interaction or interplay and institutional change. In other words, the existing literature focuses on synergies and other benefits (or problems) brought about by institutional interaction or interplay. The existing institutional theory does not define how a change in a specific rule system in one institutional reality leads to a dialogical process that facilitates changes in institutions operating in another reality. The concept of institutional feedback focuses specifically on these developments and their contributions to institutional changes, both in connected institutional realities and in the overall institutional environment related to a particular phenomenon.

In the present study, I use the terms institutional interaction and interplay as features of favorable governance systems at a general level, but I do not consider those attributes to be features of institutional feedback. I argue that institutional change is fashioned in the interplay between different institutional realities, and significantly, feedback and institutional obstacles operate in that interplay. I certainly agree with Oran Young that, if an institutional regime fits well into the biophysical operational system whose actions it is supposed to dictate, then the interplay between the regime and the operational system probably increases and may lead to various kinds of positive outcomes. However, in some situations theory of interplay and fit may face challenges, especially in their capacity to explain concepts' specific relationships to institutional obstacles. For example, it can be difficult to explain whether a particular obstacle is a consequence of lack of interplay or

a problem of fit (Vatn and Vedeld, 2012, 7-8). In contrast, a careful description of a feedback mechanism probably facilitates definition of the exact relationship between the feedback and the specific obstacle.

2.3.2 FEEDBACK AS A MECHANISM

There are two reasons why institutional feedback is important in the context of this dissertation. First, it enables theoretical elaboration of the dialogical processes between the formal and informal institutional realities of industrial manufacturing in a manner that maintains close connection with the empirical case studies. Second, it allows such insights to be comprised from several theories which are essential, not only to understanding the core idea of institutional feedback, but also to demonstration of its capacity to explain the institutional change in complex operational environments.

Above, I defined institutional feedback as the *maintenance of knowledge exchange between formal and informal institutions*. The main argument in this dissertation is that institutional feedback may – under certain circumstances – facilitate overcoming institutional obstacles to industrial recycling. In sections below, I will consider institutional feedback as a “mechanism” that can be observed, studied, and, in some cases, strengthened by means of novel institutional arrangements. The role of institutional feedback as a schematic procedure or a “mechanism” is emphasized because I focus on normative forms of feedback which are aimed either at promoting industrial recycling or resolving relatively clearly defined problems related to it. However, despite the relatively narrow empirical and theoretical focuses of this dissertation, it is important to be aware of the enormous amount of theoretical and empirical work on institutional feedback that provides the groundwork for my notions in the context of industrial recycling.

In the literature, institutional feedback does not always appear as a “mechanical process” that can be repeatedly verified or “adjusted” through trial and error. By nature, institutional feedback is a fundamental process of human interaction that functions at all levels of social intercourse – from personal relationships to those of international organizations. Through institutional feedback we reproduce and modify the structures and belief systems on which our societies are built. Deeper understanding of institutional feedback requires distinct theoretical resources; thus, in the next section I will shed light on some strains of thought that are particularly helpful in the context of my work. It will become clear that, while *maintenance of knowledge exchange between formal and informal institutions* is a functional definition for the institutional feedback in this dissertation, it is still only one part of a much wider story.

2.3.3 TWO PERSPECTIVES ON INSTITUTIONAL FEEDBACK

Two types of literature, which I call *institutional policy analysis* and *deliberative policy analysis*, offer a starting point for understanding the structure, functional logic, and theoretical relevance of institutional feedback. I found it useful to sketch these approximate categories because they help to clarify numerous issues that, in different ways, are connected to institutional feedback. At the same time, it needs to be emphasized that these categories are just rough generalizations that position vast bodies of diverse literature in simplified classes. The only purpose of these categories is to set the stage for understanding the logic of institutional feedback in the context of this research. I will briefly introduce the basic categories, and then turn to the diversity of approaches within and between categories.

Both institutional and deliberative literature on policy analysis deal with similar empirical and theoretical contents, but their analytical perspectives are somewhat different. In a way, the literature on institutional policy analysis describes theoretically the social and cognitive structures in which institutional feedback operates, while the literature on deliberative policy analysis introduces the functional logic and ethical justification of institutional feedback. In Figure 2, I have characterized the literature on institutional and deliberative policy analyses within the descriptive versus prescriptive analysis of feedback, and communicative versus dispositional views of the logic of feedback. Within these dimensions, we can say that institutional literature on policy analysis is, by definition, more descriptive and more focused on dispositional features of institutions and the forms of feedback between them. Deliberative literature, in turn, is more prescriptive by nature and more focused on communicational functions of institutions. Next I will describe the rationale behind these categorizations.

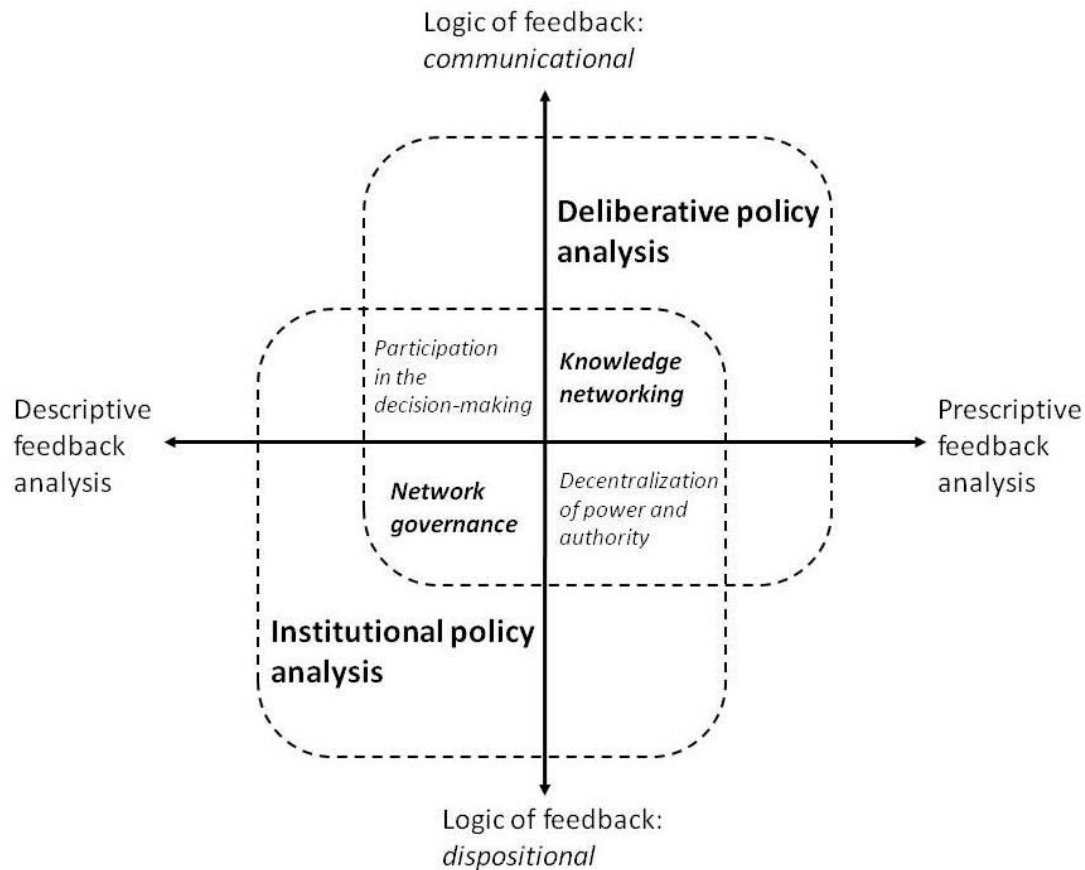


Figure 2. *Theoretical perspectives on institutional feedback.* (The form of the figure is inspired by Berg, 2012, 27.)

Institutional policy analysis – as I treat the term – is mainly built on the works of eminent scholars associated with the field of *new institutionalism*. Key figures include Douglass North, Oran Young, Elinor and Vincent Ostrom, and their countless collaborators and academic descendants (e.g., North, 2005; Young, 2002; Ostrom, 2010; Ostrom and Hess, 2011). These researchers have incorporated a cognitive dimension of institutions into their empirical policy analyses. This means that they have considered the profound implications of different types of rules on human behavior and vice versa, that is, the implications of cognitive factors on different rule systems. Policy analysts who follow this strain of theory typically endeavor to understand how institutions affect behavior beyond traditional decision-making situations. Fine-grained rule systems are found in intentions and unconscious habits, and new institutionalism seeks to understand the interconnections of these systems with surrounding cultural, cognitive, and biophysical factors. In this kind of analysis, the assumed logic of institutional feedback is mainly dispositional because the feedback is expected to affect behavior by reinforcing the existing habitual or behavioral tendencies. This emphasis also distinguishes new institutionalism from more traditional or “old” institutionalism, which stresses the importance of rational decision-making and *choice*. (*Articles II and IV*; Peters, 2011; Rutherford, 1996).

The literature on deliberative policy analysis, on the other hand, has been built on two conceptually different, yet famous and influential theoretical pillars: Jürgen Habermas's idea of *communicative rationality* and John Rawls's idea of *public reason* (see, e.g., Habermas, 1984; Rawls, 1972). Such pioneering figures of policy and planning sciences as John Dryzek, Frank Fischer, John Forester, and Maarten Hajer have been instrumental in the further development of Habermasian and Rawlsian insights (see, e.g., Hajer and Wagenaar, 2003; Dryzek, 2010; Fischer, 2000; Forester, 1999). Most importantly, these scholars have paved the way for the operationalization of deliberative methods both in research and in everyday policy-making. The prescriptive orientation of policy research has been an integral part of the deliberative literature since its early stages. The key idea is that, through transparent communication, actors can engage in collective decision-making and thus achieve good and widely accepted decisions. In deliberative policy analysis, institutional feedback means communication between the actors, and because the focus is on communication and better decision-making, the analytical perspective on institutional feedback is profoundly different than in institutional policy analysis. (*Article III*).

2.3.4 NETWORK GOVERNANCE AND KNOWLEDGE NETWORKING AS COMPONENTS OF INSTITUTIONAL FEEDBACK

As illustrated in Figure 2, the literature on institutional and deliberative policy analyses not only shares similar interests with respect to empirical and theoretical contents, but also overlaps each other. This overlapping becomes evident at closer explication of the key concepts in both types of literature. "Network" is a good example of key concepts that are important for both institutional and deliberative analyses, but is also discussed in slightly different ways in each type of literature. Below, I will demonstrate some of my points related to institutional feedback by means of different conceptualizations of the *network*. There are two reasons why I selected this concept as a basis for my description of institutional feedback. First, institutional feedback operates in networks, which is the reason an analyst (or a facilitator) of such feedback needs a solid theoretical grasp of the functions of networks. Second, an examination of network conceptualizations in two types of literature opens up important perspectives on the functioning and structure of institutional feedback. In the remainder of this section, I focus on the literature that may be positioned in the overlapping area of the two-dimensional schemata shown in Figure 2.

In institutional policy analysis, governance theory, which highlights the decentralization of power and authority, has been very influential since the 1990s (e.g., Stoker, 1998; Rhodes, 2007; Levi-Faur, 2012). At the core of the theory is the notion of the actors' informal collaboration and communication through self-emerging networks. Toikka (2010, 136) captures the meaning of

networks within governance systems as follows: “...the concept of network is often underdeveloped in governance research ... networks are assumed to be simple membership structures, but real life governance systems are complex communication structures, where the interplay of institutions produces policy.” Discussions of networks in this context deal with actors’ capability or dispositional tendency to maintain networks, which can also be called *network governance* (Figure 2). Network governance is a term that complements my discussions on governance (*Article II*, 15-16) and networks (*Article IV*, 548). Network governance can be defined as “articulation of interdependent, but operationally autonomous actors, who interact through negotiations that involve ... deliberation ... which takes place within a relatively institutionalized framework of contingently articulated rules, norms, knowledge and social imaginaries” (Sørensen and Torfing, 2005, 197).

Collaboration and communication within and between actor networks are also favorable aspects of “good governance” in deliberative literature. The bulk of this literature evaluates the forms of participation in decision-making situations and the efficiency of policy designs aimed at weighting different opinions on controversial policy problems equally. There is also an important subsection in the deliberative literature that focuses on the processes of knowledge production and integration. These processes are central to institutional feedback because often the purpose of the feedback is not to negotiate on compromises, but rather to create new understanding of the issues at hand (*Article III*). In Figure 2, following Bruun et al. (2005) and Hukkinen (2008), I call this strain of theory *knowledge networking*. I discuss both practical and theoretical meanings of knowledge networking in *Articles I* and *III*. Knowledge networking can be defined as “learning and knowledge production by interaction across epistemically defined boundaries between knowledge agents, such as individuals, groups, or organizational units” (Bruun et al., 2005, 86). Knowledge networking offers an important perspective on institutional feedback because it forces an analyst to think not only of the institutional structure that enables the feedback, but also of the ways in which different knowledge structures are brought into the dialogical process (see also Honkela, 2011, 46-54).

To summarize, we can say that both network governance and knowledge networking attach value to knowledge exchange in functional networks from different points of view. Network governance focuses on the conceptualization of the maintenance, management, and coordination of networks in which collaboration and communication happen. Knowledge networking focuses on the conceptualization of knowledge production and knowledge structures within and between networks. These two perspectives are crucial for understanding institutional feedback, defined as simultaneous management of both network structures and the processes of knowledge exchange. Network governance and knowledge networking provide

conceptual tools to understand these two dimensions at the same time, and thus they may also reveal the functioning of institutional feedback.

2.3.5 PERSPECTIVES ON NETWORK GOVERNANCE AND KNOWLEDGE NETWORKING

Network governance and knowledge networking can also be considered conceptual anchors, which are useful in determining the exact functions of institutional feedback in different situations. Figure 3 zooms into the center quadrangle of the two-dimensional schemata of Figure 2 and introduces some concepts that I have found useful in the conceptualization of different dimensions of institutional feedback in the four research articles. The idea in the figure is that concepts placed close to a “knowledge networking corner” shed light on the meaning of knowledge exchange within and between networks, while concepts close to the “network governance corner” shed light on the meaning of the management and maintenance of networks that are important to institutional feedback. These two groups of concepts are illustrated by grey circles in Figure 3.

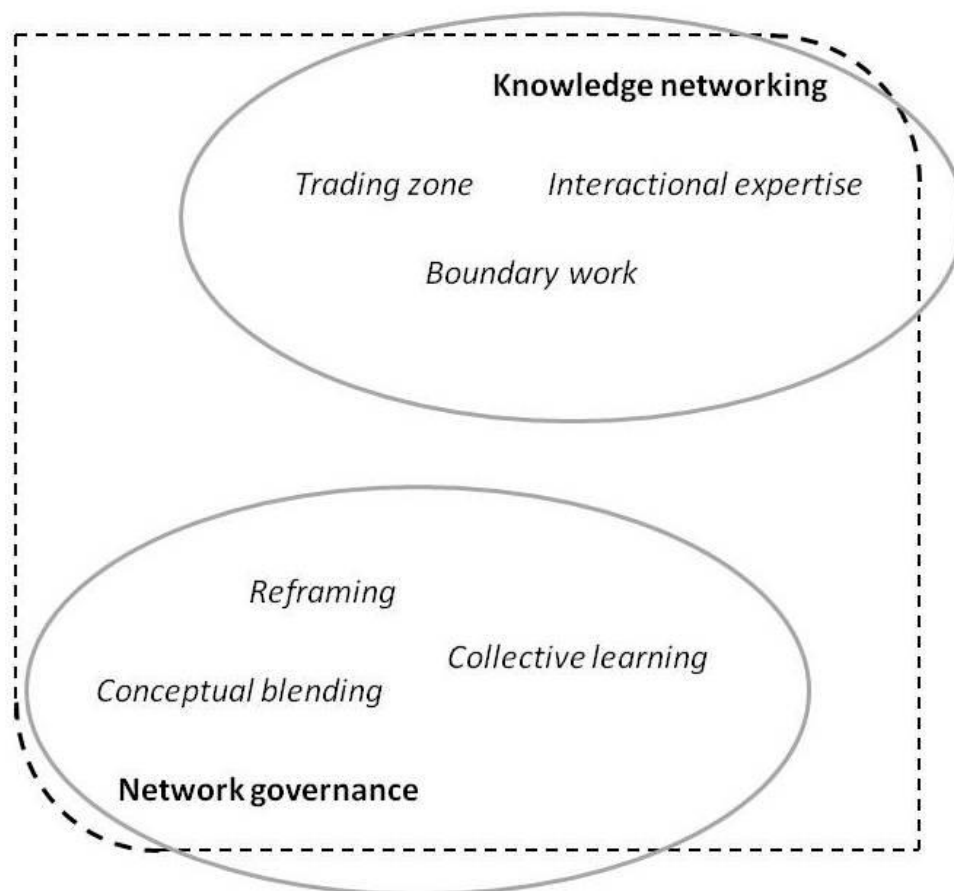


Figure 3. Analytical perspectives on network governance and knowledge networking.

The placing of concepts in the quadrangle in Figure 3 is merely indicative at best, because each concept shares common features with both network governance and knowledge networking. The concepts that I have used should be considered examples of theoretical tools that can be used in the identification of different features of institutional feedback, not as an exhaustive list of the tools that are available. Additionally, two things related to Figure 3 need to be emphasized: first, the case-specific roles of network governance and knowledge networking as components of institutional feedback vary, depending on the situation; second, the capability of different concepts to explain the functioning of different “parts” of institutional feedback always depends on situational factors.

The more general message of the concepts introduced above is that an analyst who sets out to explicate the functions of institutional feedback in different situations probably needs various theoretical resources and methodological tools. This point can be demonstrated by some of the situations I have studied. Depending on the circumstances, knowledge networking can mean anything from a collaborative reflection of different views of a particular issue to the creation of new knowledge through an intense collective learning process (*Articles II, III and IV*). Similarly, network governance can mean anything from the management of a self-emerging network so that the thematic focus remains somewhat clear to the maintenance of a formal dialogical process among the actors representing conflicting views (*Articles II and IV*). In Table 1, I illustrate the concepts presented in Figure 3 in the contexts of the above-described examples of research situations.

Concept(s)	An example of the research situation	Used in article(s)	References
<i>Conceptual blending</i>	How is the integration of existing knowledge transformed into a new understanding of the situation at hand?	II	Fauconnier and Turner (1998)
<i>Collective learning, reframing</i>	How can actors engage in a collective learning process, i.e., interactional creation of new knowledge?	IV	Pahl-Wostl et al. (2007); Schön and Rein (1994)
<i>Boundary object, boundary work</i>	How can actors manage a working process that takes place in self-emerging networks?	III	Star and Griesemer (1989); Gieryn (1983)
<i>Trading zone, interactional expertise</i>	How can we understand the prospects for expert collaboration in tense or politically sensitive situations?	III	Galison (1997); Collins (2004)

Table 1. *Examples of concepts used in the identification of different aspects of institutional feedback.*

The purpose of Figure 3 and Table 1 is to underline the point that institutional feedback always consists of both of its components, i.e., network governance and knowledge networking. If either of these components is weak or nonexistent, then institutional feedback is weak or nonexistent. This issue also has implications for the analysis of institutional feedback: the importance of two components as explanatory factors for the feedback may vary, yet both components should still be included in the analysis if the aim is to understand the functioning and the structure of institutional feedback. Examples of research situations presented in Table 1 demonstrate some aspects that may be important in understanding such feedback in particular situations. The more general point, however, is that, as separate analyses, they do not actually reveal the functioning of institutional feedback. When the results of analyses of knowledge networking and network governance are combined, it is possible to view the studied phenomenon from a wider perspective and understand the logic of institutional feedback in that particular context.

2.4 THE PROCESS OF INSTITUTIONAL CHANGE

I have argued earlier that industrial manufacturing and its development take place in the interplay between formal and informal institutions (section 2.1). The purpose of institutional feedback is to facilitate this interplay by accelerating changes in both formal and informal institutions. The overall process is called institutional change, which in this dissertation also means the institutionalization process of industrial recycling. Knowledge networking and network governance provide different ways of understanding the various functions of institutional feedback and its role as a facilitator of institutional change. Figure 4 illustrates some of these ways. Next I will turn to the theoretical connections between institutional feedback and institutional change. I will also come back to this issue in *Discussion and conclusions* section, when I contextualize the relationship between institutional feedback and institutional change in industrial management.

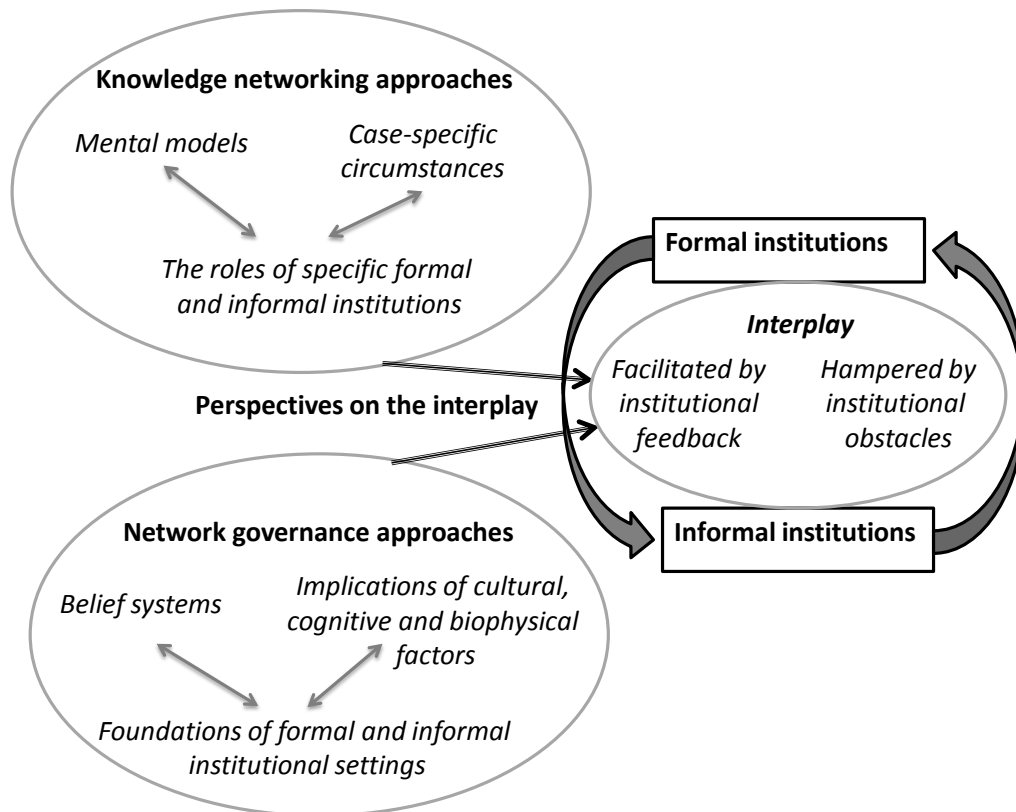


Figure 4. Perspectives on the interplay between formal and informal institutions.

Above, I made the argument that institutional feedback means simultaneous management of both network structures and processes of knowledge exchange. Network governance and knowledge networking are conceptual

umbrellas that include different tools with which to observe these components of institutional feedback in different situations. Through these dimensions, it is also possible to approach the relationship between institutional feedback and institutional change. Conceptual tools associated with network governance help in a consideration of the prospects of institutional change from a broad perspective. As illustrated in Figure 4, a network governance approach enables us to evaluate the roles of different belief systems and the implications of cultural, cognitive, and biophysical factors for the institutional foundation on which specific formal and informal institutions are built. This kind of evaluation is crucial if the aim is to understand what changes in formal and informal institutional realities are required to achieve wider institutional transformation.

Conceptual tools associated with network governance describe what kind of network is required by institutional change and how that network can be managed and maintained in different situations. In a way, a knowledge networking approach makes it possible to continue and sharpen the analysis from the point reached through a network governance approach. Conceptual tools associated with knowledge networking clarify the roles of single institutions and their links to different actors' mental models (Figure 4). These tools enable us to define what kind of knowledge is needed to facilitate changes in formal and informal institutions in order to accelerate wider institutional change.

The basic idea in Douglass North's (1991) argument is that the existing institutional setting always reflects peoples' mental models, and thus profound institutional change requires a change in the belief system or "ideology." Because the institutional structure is supported by established beliefs, institutional change can only take place when the underpinnings of the dominant belief system are revealed and exposed for discussion. This in turn requires: 1) the ability to identify those underpinnings, and 2) the ability to initiate a dialogical process that involves the relevant stakeholders and deals with those bounded aspects of underpinnings that are collegially accepted as important. At the same time, it is important to note that while institutional change is typically a slow process, it can also take place rapidly if the agent of change manages to convince the public of its necessity. Occasionally, North calls the agent of rapid institutional change an *ideological entrepreneur* (North, 2005; see also Storr, 2008). I will utilize this term in *Discussion and conclusions* section.

3 THE CASES AND THE METHODS

3.1 INDUSTRIAL RECYCLING IN FINLAND

The empirical part of the dissertation deals with Finnish *basic industries*. “Basic industry” is a term that defines fields of industries which have been important for the long-term economic development of a particular country (Cambridge Online Dictionary). In Finland, the basic industries have traditionally included different forms of the metal, wood-processing- and chemical industries. These industrial fields have been the backbone of the Finnish economy for decades. Finnish basic industries are also resource intensive in the sense that they transform large amounts of raw materials into products and residuals; for that reason I also call these industries *heavy industries*. Resource intensity together with a remote geographical location makes Finland an interesting case in the development of industrial recycling, which is very different there compared with countries located in areas with intensive residuals markets, such as Central Europe.

Three incentives have spurred Finnish industrial companies to seek regional cooperation in material efficiency. First, Finnish heavy industries produce large amounts of utilizable residual materials (e.g., Ministry of the Environment, 2009). Second, for a long time the most significant residual flows have been relatively small in number. And third, international retail prices of residual materials have generally been relatively low, and thus their long-distance transportation from Finland to international markets quickly becomes unprofitable. (*Articles II and IV*). Because the volumetric amount of available residual material has been large while the number of materials has been small, Finnish companies have gained expertise in the development of relatively simple recycling products whose demand is high, yet which are based on few ingredients. Different slag-based soil construction products are good examples of this kind of recycling product (*Articles II and IV*).

3.2 FIELD SITE: THE FINNISH SIDE OF THE BOTHNIAN ARC REGION

The main empirical material for this study is drawn from the industries located in the Bothnian Arc region. The region is comprised of the coastal areas of the northernmost end of the Baltic Sea and includes land areas belonging both to Finland and to Sweden. The location of the region is shown in Figure 5. The region represents a mixture of urban, semi-rural, and rural areas and its total population is about 710 000. Many Nordic heavy industries are concentrated in the Bothnian Arc region, where the average size of industrial units is also remarkably large (see, e.g., Salmi et al., 2011).

This is understandable because numerous mineral sources and large commercial forests are located nearby. The region's coastal areas are also easily accessible: there are, for example, numerous industrial harbors and good train connections to Europe and Russia. The industrial companies I have studied are located in the Finnish part of the Bothnian Arc region, which serves as the field site for this research (see Figure 5).

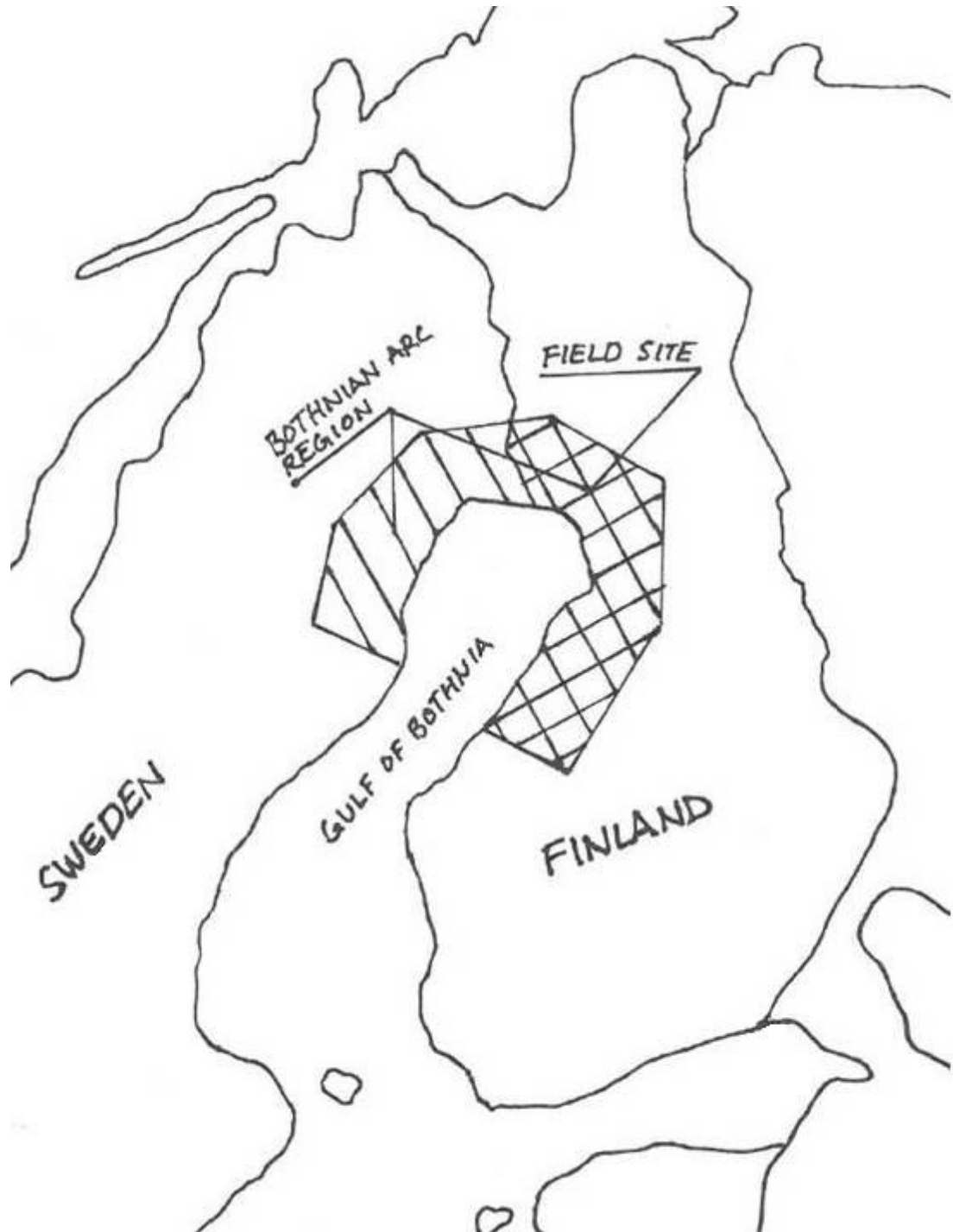


Figure 5. *The Bothian Arc region and the field site for the research.*

The studied industries are located in four Finnish municipalities: Kokkola, Kemi, Tornio, and Raahе. These municipalities are relatively small compared to average Nordic cities, yet they are relatively large compared to other municipalities in the northernmost parts of Scandinavia. The population of the four case-study municipalities varies between 22 000 and 47 000, and the total population of all four is about 115 000 inhabitants. The municipalities' land areas vary between 95 and 1400 square kilometers, and the total land area is about 3700 square kilometers. Figure 6 provides a detailed map of the field site and shows the locations of the case-study municipalities and of the companies studied in each municipality. The selected companies represent all fields of Finnish basic industries; their main products, production capacity, and numbers of employees are presented in Table 2.

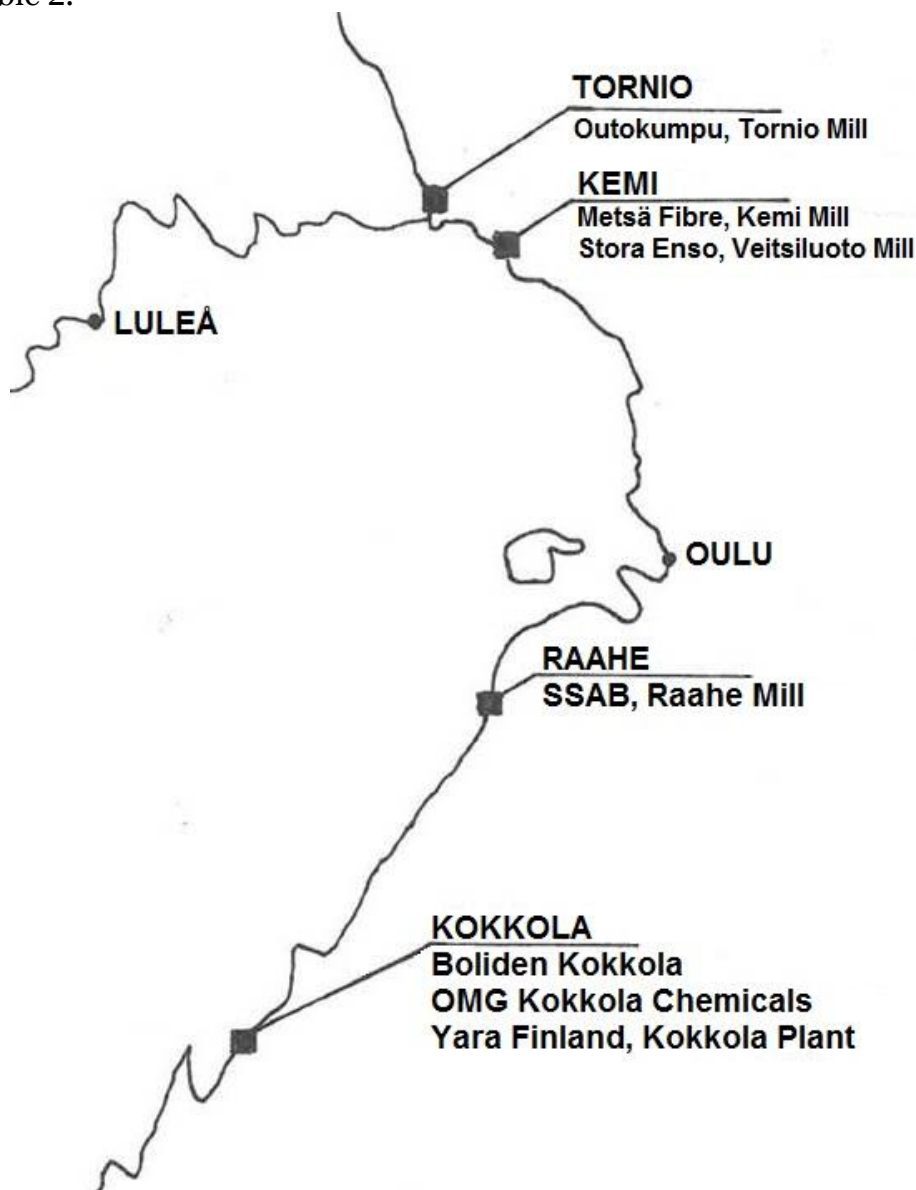


Figure 6. Case study municipalities and the studied companies.

Industry	Main products	Production capacity (tonnes of main products / year)	Number of employees
1. Outokumpu, Tornio mill	Stainless steel products (ferrochromium)	~434 000	~2100
2. Metsä Fibre, Kemi mill	Chemical pulp products (softwood and hardwood pulps)	~590 000	~170
3. Stora Enso, Veitsiluoto mill	Paper products (magazine papers and office printing papers)	~815 000	~1000
4. SSAB, Raabe mill (referred to as Ruukki metals Inc. in <i>Article IV</i>)	Steel products (heavy plate and strip products)	~2 200 000	~2100
5. Boliden Kokkola	Zinc products (pure zinc and zinc alloys)	~315 000	~540
6. OMG Kokkola Chemicals	Cobalt products (cobalt chemicals and powders)	~16 000	~400
7. Yara Finland, Kokkola plant	Fertilizer products (potassium sulfate)	~200 000	~110

Table 2. *Key facts about the studied industries* (sources: companies’ annual reports and websites).

3.3 CASE-STUDY METHODOLOGY

This dissertation consists of four case studies. According to Yin (2009, 18), “[a] case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” As discussed in the previous section, it is difficult to formulate a comprehensive definition of the context of industrial recycling. Depending on the situation, an analyst who wants to understand different aspects of industrial recycling needs to balance the institutional, social, economic, and technological contexts. All of these are dimensions of the “real-life context” of industrial

recycling, but their importance and meaning depend on the situation. The case-study method is also suitable for exploring large and multidimensional phenomena which cannot be studied in depth as a whole. A small number of well-designed and focused case studies can open up important perspectives on a topic. These perspectives in turn make it possible to reveal the wider dynamics at play (e.g. Hammersley and Gomm, 2000; Yin 2009).

Industrial recycling is an *example par excellence* of a phenomenon that cannot be studied in depth as a whole, and thus the case-study method is appropriate to use for this dissertation. Four separate case studies construct a picture of industrial recycling in Finland, and each is presented in detail in the respective research articles (*Articles I-IV*). The case studies explicate different institutional obstacles to industrial recycling and offer tools with which to work on specific obstacles. Through the dissertation in its entirety, the logic of case study methodology is illuminated: it would not be possible to understand fully the proportions of industrial recycling without understanding its contemporary challenges. In the case-studies, these challenges are interpreted in different ways, and thus each study also helps to conceptualize the wider dynamics of industrial recycling. Table 3 summarizes the theoretical and empirical contents of each case study and points out the field site industrial companies relevant to each individual case-study (the numbering of related field site industries is presented in Table 2).

Case studies	Key theoretical content	Key empirical content	Related field site industries
<i>Case study 1</i> (<i>Article I</i>)	Demonstration of the functioning of an institutional obstacle	Evaluation of the prospects for mineralization-based carbon storage	4
<i>Case study 2</i> (<i>Article II</i>)	Evaluation of the organizational prospects for informal institutional feedback	Identification and collective elaboration of institutional obstacles to industrial recycling	1-7
<i>Case study 3</i> (<i>Article III</i>)	Evaluation of the organizational prospects for formal institutional feedback	Experts' collaboration opportunities in the policy reformulation process	1-7
<i>Case study 4</i> (<i>Article IV</i>)	Demonstration of the functioning of an institutional feedback mechanism	Interplay between formal and informal institutions in the product innovation process	1-7 (with special focus on 1, 3, and 4)

Table 3. *The key contents of the four case-studies.*

The case-studies also draw a picture of various conceptions related to industrial recycling. The second and the third studies demonstrate a conception of industrial recycling that is perhaps the most traditional. In these cases, industrial recycling means utilization of industrial leftover materials as raw materials or as products. The fourth case study expands this conception. Here, industrial recycling not only means the utilization of leftover materials as products or raw materials, but also as ingredients of completely new product concepts. Finally, the first case study represents the most advanced conception of industrial recycling. Here, industrial recycling means intelligent utilization of a steel mill's CO₂ emissions by means of the mineral carbonation method, i.e., mineralization. Mineralization enables the storing of CO₂ into industrial residues and different rock materials, and in optimum conditions, leads to a simultaneous decrease in emissions and an increase in material efficiency.

3.4 DATA

The empirical material for the case studies has been gathered from various sources. The data consist of semi-structured interviews, questionnaire-type surveys, documentation of group discussions, personal communications, numerical data, results of previous research, and other documentary sources. The basic information on the different types of data sets and their relevance to specific case studies is summarized in two tables: Table 4 presents those data sources whose collection involved direct communication with the informants; Table 5 presents forms of data that are based on previously documented information. Detailed information concerning the qualities of different data sets and their collection processes are presented in the related research articles.

Types of data	Description of the informants	Number of informants	Case studies	
Thematic interviews Stakeholders in material recycling	Representatives of industrial companies, administration, and environmental and industrial interest groups	17	2-4	
	Stakeholders in carbon capture and storage (CCS)	Representatives of industrial companies and research institutions	9	1
Questionnaire Members of the working group on the preparation of a new Waste Act	Representatives of administration and environmental, societal, and industrial interest groups	6	3	
	Experts who followed the preparation of a new Waste Act	Representatives of administration, research institutions, government agencies, communal unions and consultancy companies	8	3
	Members of the working group on landfill taxation	Representatives of administration	4	3
	Experts who followed the preparation of landfill taxation	Representatives of administration and environmental and industrial interest groups	6	3
	Industrial actors	Representatives of the field site industrial companies	4	4
Documentation of group discussions Notes from researchers' brainstorming session	Researchers of energy technologies, material and wood processing technologies, and environmental law and policy	6	2	
	Notes from stakeholders' workshop	Researchers from the above-mentioned fields, representatives of field site industrial companies, administration and interest groups	22	2, 4
Personal communications Email communications	Representatives of industrial companies	4	4	

Table 4. Summary of interviews, questionnaire surveys, documentation of group discussions, and personal communications.

Types of data	Description of the data source	Case studies
<i>Numeric data</i> Corporate reports	SSAB Raahe mill's annual environmental reports from the years 2007, 2008 and 2011	1
<i>Results of existing research</i> Research articles	Mäkelä et al., 2010; Mäkelä et al., 2012 Arasto et al., 2013a; Arasto et al., 2013b; Tsupari et al., 2013	4 1
<i>Legal documents</i> EU legislation	Waste Framework Directive (2008/98/EC) Directive on Carbon Capture and Storage (2009/31/EC)	2-4 1
Finnish legislation	Waste Acts (1072/1993 and 646/2011) Waste Tax Act (1126/2010) Fertilizer Product Act (539/2006) Act on Carbon Capture and Storage (416/2012)	2-4 2-3 2-4 1
Finnish court decisions		
Northern Finland Env. Permit Authority	Decision n:o 8/02/1	4
Vaasa Admin. Court	Decision n:o 03/0106/3	4
Supreme Admin. Court	Decision n:o KHO 2005:90	4
Regional State Admin. Agency of Northern Finland	Decision n:o 133/12/1	4
<i>Other documents</i> Documentation related to the preparation of new waste legislation	Proposal for new waste legislation in Finland Dissenting opinions on the proposal for new waste legislation Summary of the official statements for the proposal for new waste legislation	3 3 3
Documentation related to the preparation of new waste tax legislation	Memo document on landfill taxation Official statements for the memo document on landfill taxation	3 3

Table 5. *Summary of the documentary data.*

4 FINDINGS

In the Introduction, I posed the following research questions:

1. *How do institutional obstacles hamper the development of industrial recycling?*
2. *How does institutional feedback function in an industrial operational environment?*
3. *What is the role of institutional feedback in overcoming institutional obstacles?*

My answers to the first and second questions consist of evaluating practical examples that describe the functioning of institutional obstacles, a feedback mechanism in the contexts of carbon capture and storage (CCS), and industrial material recycling in field site companies. My answer to the third research question synthesizes information from various empirical examples and the theoretically-oriented literature. That answer also illustrates more generally the role of institutional feedback in overcoming institutional obstacles.

4.1 HOW DO INSTITUTIONAL OBSTACLES HAMPER THE DEVELOPMENT OF INDUSTRIAL RECYCLING?

CCS refers to a process in which CO₂ emissions are first captured from their source, then transported to a storage site and finally stored in a permanent location. For a relatively long time, distinguished research communities, such as the Intergovernmental Panel for Climate Change (IPCC) and the International Energy Agency (IEA), have considered CCS to be one of the key methods for mitigating climate change globally (e.g., Metz et al., 2005; IEA, 2013; IPPC, 2014). Thus far, however, the public acceptance of CCS has been relatively low, while the development of the technology has faced unexpected challenges (e.g., Karimi and Toikka, 2014). For these reasons, CCS has not yet been widely implemented. However, its popularity is likely to rise in the rather near future because different policy incentives, such as the EU's emissions trading system (EU ETS), are gradually making the use of CCS more cost-efficient and thus more interesting for potential users. Additionally, thus far CCS has been perceived as belonging only to the world of community energy production; however, the new incentives are likely to increase its attractiveness to actors in other carbon-intensive operations, such as heavy industries. (*Article I*).

Traditionally, the “storing-step” of the CCS process has meant the injection of CO₂ into deep reservoirs located underground or beneath the

seas. This method of CO₂ storage is called *geological storing of CO₂*. Almost all existing implementations of CCS employ different forms of the geological storing method (GCCSI, 2013). However, it is also technically possible to store CO₂ in other kinds of locations. The examples presented in *Article I* demonstrate the potential of emerging CCS applications based on *mineralization* method. Commercial, mineralization-based CCS applications are still being developed, but it has already become clear that the mineralization method allows conversion of CO₂ into solid inorganic carbonates that are easier and cheaper to access than geological CO₂ storing locations (*Article I*; Kainiemi et al. forthcoming). In addition, in mineralization-based methods there is practically no risk of CO₂ leakage, and no post-storage monitoring of CO₂ is needed.

Many heavy industrial manufacturing processes generate suitable carbonates for the mineralization of CO₂ emissions. Utilization of these carbonates by means of mineralization not only increases the material efficiency of manufacturing processes, but also can mean new possibilities for the side-production of novel by-products, such as pure, precipitated calcium carbonate (*Article I*). In practice, this means a completely new kind of thinking about the “CO₂ emissions” and their relationship to other resources. Now “emissions” are not something to be gotten rid of, but instead are a source of innovation. In *Article I*, we argue that this kind of systemic approach, which simultaneously values both material efficiency and carbon sequestration, should be adopted as the core of industrial development (see also Brent et al., 2011). The basic idea of mineralization seamlessly follows the basic ideas of industrial ecology, and therefore *Article I* concludes that, in the future, mineralization-based CCS can function as a facilitator of new and more efficient industrial symbioses.

At the same time, however, *Article I* demonstrates the functioning of an institutional obstacle that hampers the development of mineralization in the EU. The institutional obstacle in this case is the insufficient definition of the carbon storage method in the EU’s CCS directive, which describes CCS as an “environmentally safe capture and *geological storage ... of CO₂*” (Directive 2009/31/EC of the European Parliament and of the Council, article 10a; italics added). In other words, only the geological method of storing CO₂ is considered a “CCS method” in the eyes of the EU. This demarcation means that all applications that are not based on geological storage of CO₂, such as mineralization-based applications, are formally disassociated from all policy mechanisms that have been created to support the development and implementation of CCS. For example, if an industrial actor would like to employ a mineralization-based application to reduce the CO₂ emissions generated by a particular manufacturing process, she would not be eligible for any economic compensation through the EU ETS mechanism. Moreover, because the emerging methods are positioned outside the formal CCS regime, it is very difficult to find interested funders to support their development.

The legal definition of CCS in the EU functions as an institutional obstacle which hampers the scaling-up of emerging CCS applications, despite their promising potential. The definition of CCS by the EU demonstrates insightfully the logic of an institutional obstacle. Recall (section 2.2) that, despite their origin, institutional obstacles operate between formal and informal institutional realities. In this case, the obstacle obviously originates in the formal institutional reality because the obstacle itself is a formal definition. The functions of the obstacle, however, take place between the two institutional realities. The institutional obstacle basically disconnects the actors of these realities from each other. Additionally, in this case, the institutional obstacle mobilizes undesired developments in both formal and informal institutional realities. Among CCS experts, the situation reinforces the marginalization of emerging CCS methods and thus hampers their development and implementation. Among the actors in the formal institutional reality, this obstacle hampers the achievement of the ambitious targets set for CCS. (*Article I*).

4.2 HOW DOES INSTITUTIONAL FEEDBACK FUNCTION IN AN INDUSTRIAL OPERATIONAL ENVIRONMENT?

The institutional obstacle introduced above was relatively simple. Its particular formal definition straightforwardly prevented certain activities in the operational environment. Such an institutional obstacle is rather easy to identify, and its functions and implications are relatively clear. Here I introduce another institutional obstacle whose working logic is similar to the previous example, but is more complicated. The example comes from industrial material recycling and was first identified in the interview data concerning the field site companies. Once again, the obstacle originates in the formal institutional reality, and again it deals with the formal definitions of critical issues. This time the institutional obstacle is the formal definition of residual materials. In *Article IV*, I have illustrated in detail how the legal definition of residual materials affects their recoverability. The formal distinction between the definitions of *waste* and *by-product* is especially important for industrial companies because they can do business with by-products, whereas waste management causes them extra costs for them. *Article IV* demonstrates how the inappropriate definition of residual materials may practically prevent their reasonable utilization.

The formal definition of industrial residual materials is a more complicated obstacle than the formal definition of the CCS method because, by nature, its functions and implications are more case-specific. The formal definitions of companies' residual materials are operationalized in their environmental permits, and the classifications must be in line with the legislative distinction between waste and by-product. In practice, because of the multitude of wastes and by-products generated by different industrial

processes, definitions are specified separately for each company. Furthermore, definitions can change, for example, during environmental permit revisions, as described in *Article IV*. The definitions of waste materials and by-products directly affect the operational environment of companies because they define permissible and impermissible material management activities. The environmental permit procedure may also limit opportunities for the development of industrial recycling because permits are generally valid for several years, during which time material management operations remain more or less “formally locked” (*Article II*).

Presently, however, the situation related to the formal definitions of industrial residual materials is changing in the EU countries. In 2008, the EU introduced new principal guidelines for a by-product definition in the Waste Framework Directive (European parliament and the council of the European Union, 2008). The new guidelines are called *by-product criteria* (see *Article IV*, 543-444, for the specific terminology), and these criteria define what is required for waste material to be classified as a by-product. The directive has led to waste legislation reforms in European countries. As a result, many countries, including Finland, have introduced revised national waste legislation, which includes the by-product criteria in a form similar to that in the directive. In *Article III*, I have described in detail the preparation process of the new waste legislation in Finland, while in *Article IV*, I introduce the practical implications of the by-product criteria for material management practices among the field site industrial companies.

The main policy improvement resulting from the by-product criteria is that industrial companies are allowed to consider the potential for their residues to be qualified as products or raw materials. If industrial actors come up with a suitable residual-based product concept (or a potential raw material), they can appeal to the criteria to change its legal status to that of a by-product (or a raw material) instead of waste. And if the material meets the requirements of the criteria, the authorities must accept the change. Consequently, by-product criteria represent a mechanism that allows an active role for “the target audience” of policy intervention. It is important to note this shift in the “target point” of a policy: compared to previous EU and national legislations, by-product criteria change the policy target from the industrial activity to the interplay between institutional realities. Now, recall (section 2.3) that institutional feedback means *maintenance of knowledge exchange between formal and informal institutions*. By-product criteria evidently enhance and maintain the knowledge exchange between authorities and industrial actors and thus should be considered a formal institutional feedback mechanism. (*Articles II and IV*).

Compared to institutional obstacles that disconnect groups of actors, institutional feedback mechanisms operate in the opposite way: they provide formally or informally defined “channels” that enable the collaboration of different actors around specific themes. Optimally, an institutional feedback mechanism can launch a long-term dialogical process that leads to novel

insights in many areas. These mechanisms are especially important in the management of complex operational environments, such as heavy industries. Well-designed institutional feedback mechanisms, such as by-product criteria, allow the reasonable utilization of different actors' knowledge, and also allow new formal and informal institutions "to rise up" from such operational knowledge. This is how institutional feedback mechanisms "build bridges" between formal and informal realities (*Article IV*).

4.3 WHAT IS THE ROLE OF INSTITUTIONAL FEEDBACK IN OVERCOMING INSTITUTIONAL OBSTACLES?

In this section, I discuss the role of institutional feedback in overcoming institutional obstacles both in the industrial context and more generally. First, I would like to remind the reader of the central dimensions of institutional feedback: *network governance* and *knowledge networking*. My answer to the third research question consists of separate considerations of how network governance and knowledge networking influence the overcoming of institutional obstacles.

4.3.1 THE ROLE OF NETWORK GOVERNANCE

As discussed in the *Analytical framework* section, according to Sørensen and Torfing's (2005, 197) definition, network governance means interaction between "interdependent, but operationally autonomous actors." In *Articles II and IV*, I have described the key actor groups in industrial manufacturing in Finland, which include industrial actors, authorities and representatives of different interest groups. Sørensen and Torfing's definition works fine as a description of these groups because, in principle, they are rather autonomous. However, none of these groups alone can significantly promote increased industrial recycling. The development of recycling requires functional collaboration between groups, at the same time making them fully interdependent from each other. Following the conceptualizations of Sørensen and Torfing (2005, 197), network governance takes place "within a relatively institutionalized framework of contingently articulated rules, norms, knowledge and social imaginaries." This statement also holds true in the management of industrial manufacturing. *Article II*, for example, illustrates how actor groups can have very different conceptions of rule-systems connected to industrial management and development.

As a component of institutional feedback, network governance means the coordination and management of the network connecting different institutional realities. It is important to note that this network involves not only actor groups, which take part in the operational management of industries, but also consists of stakeholders who have different interests in

the manufacturing systems within societies. The purpose of this “extended network” is to broaden the discussion of industrial management and its development. The role of the network is emphasized in institutional change and in the situations in which institutional obstacles hamper the operational environment. Appropriate network governance may ease the adaptation of industries to changed institutional situations and enable them to overcome institutional obstacles.

Article II describes how different groups of actors can be brought into the informal dialogical process in a situation in which the formal definitions of materials function as institutional obstacles to the development of industrial recycling. In the process, experts from different backgrounds are gathered to work on themes central to the definition of the new rule system for industrial material management. *Article III* describes a similar process within the formal institutional reality. In both cases, the actors’ networks consist of representatives of different advocacy groups, and the major challenge is to maintain the dialogical process so that it leads to fruitful outcomes, despite the unavoidable disagreements. *Article IV* continues this discussion and takes it into a different context. In that case-study, network governance means the maintenance of a collaboration that enables long-term innovation management within a network that consists of actors from both formal and informal realities (see also Garud et al., 2013, 779-793).

4.3.2 THE ROLE OF KNOWLEDGE NETWORKING

Knowledge networking is another component of institutional feedback, and it means either creation of new knowledge or integration of different forms of existing knowledge. *Article III* describes knowledge networking among experts in material management and utilizes a terminology that has been developed around the *trading zone* metaphor (Galison, 1997). In the article, I compare experts’ knowledge networking in three sequences of a policy formulation process intended to overcome institutional obstacles, which in this case involve insufficient formal distinctions between waste and by-product and an imprecise conception of waste taxation. Two of the sequences represent knowledge networking in formal situations, such as officially nominated preparatory working groups, and one sequence represents knowledge networking in an informal workshop. The results of the comparison indicate that in the formal situations knowledge networking was very challenging and could barely be called integration of existing knowledge. In the informal workshop, on the other hand, knowledge networking evidently led to the creation of new knowledge.

In *Article IV*, I describe another kind of knowledge networking using the terminology of *collective learning*. I examine the prospects of residual-based product innovations in the field site industrial companies and define collective learning as *a collective reframing process of a particular issue*. In

this case, “particular issues” can mean, for example, the qualities of available materials and their combinations, the prospects of specific industrial processes, inter-industrial collaboration possibilities, the nuances of waste and by-product regulation, or issues affecting the cost-effectiveness of residual management. As defined in *Article IV*, collective learning means stakeholders’ *capability to create novel conceptions of residual materials and to modify ways of doing things within a wider community that includes authorities*.

In complex operational environments, the development of new practices usually requires knowledge networking between actors because normally systems are already optimized based on existing knowledge. Knowledge networking conceptualization reveals both smaller-scale problems related to specific issues and deeper institutional obstacles. Appropriate knowledge networking process forces participants to focus on the “right things” in a policy deliberation. I have described this kind of knowledge networking in *Article III* using *boundary work* terminology borrowed from science and technology studies (see, e.g., Gieryn, 1983; Star and Griesemer, 1989). Without appropriate knowledge networking, actors in a complex operational environment cannot anticipate the institutional changes or interpret the meanings of issues related to those changes. In these situations, there is a lack of “professional translation” related to the new phenomenon. I will return to this issue in *Discussion and conclusions* section.

5 DISCUSSION AND CONCLUSIONS

Throughout this dissertation, I have stressed that the emergence of industrial recycling should be seen as an institutionalization process within a society. In other words, a significant increase in the circulation of materials and other resources requires significant institutional change in the management of industrial manufacturing systems. I have also emphasized that proper implementation of a desired institutional setting that would guide industries toward sustainable use of resources requires an ideological change, or in other words, a change in the actors' dominant belief system concerning industrial production. At this point, the reader may ask what practical changes are needed in the development of industries and how they could be implemented. In this section, I will discuss these questions in the form of policy recommendations. Finally, I will conclude with a summary of the knowledge contributions of this work and propose of some directions for future research in the area.

5.1 INSTITUTIONAL CHANGE IN HEAVY INDUSTRIES

Douglass North's argument, namely, that existing institutional settings reflect the dominant belief system, is valid in the context of industrial development. The key problem in the institutionalization of industrial recycling is that formal institutions guiding the industrial operations related to the management of resources mainly reflect the "from use to disposal" mindset (recall *Introduction*). In that kind of institutional setting it is difficult to successfully introduce new ideas related to increased recycling. Industrial development seems to be in a situation in which, according to North's (1991) terminology, existing rules do not fit the desired game of industrial management. This insight is crucial to consideration of the deep institutional obstacles to industrial recycling. Many of the apparent problems, such as the unprofitability of recycling discussed earlier, are reflections of this deeper obstacle. To achieve the conditions in which proper institutionalization of industrial recycling may take place, a new ideology that lifts recycling to the ultimate goal of industrial resource management should be implemented by the authorities, industrial actors, and other stakeholders.

In practice, the institutionalization of industrial recycling requires continuous development of recycling innovations, which in turn requires constant dialogue among the stakeholders (*Articles I-IV*). This is how institutional feedback is constantly needed in the institutionalization of industrial recycling. To become successful in industries, institutional change must be facilitated simultaneously within both formal and informal

institutional realities, and those changes must be coordinated through institutional feedback. Change within the formal institutional reality means slowly proceeding implementation of a new ideology and the respective modification of industrial policies and formal institutions. Gradually, this development may steer an economic system toward a circular economy. This change can be viewed as a process of synchronization of the formal institutional matrix with the new ideology. Lobbyists, activists and politicians are, in North's (2005) terminology, the ideological entrepreneurs (section 2.4) driving this change; equally important are the authorities who channel the ideological changes into the modified formal institutions.

A totally different process, however, is the modification of the practices and routines within an informal institutional reality. Operational-level changes can be viewed as a modification process of informal institutions, which slowly builds up a new kind of working culture in industrial companies and collaborative organizations. Without underrating the important efforts by ideological entrepreneurs and authorities, it is important to note that, without successful implementation at the operational level, a new ideology does not actually contribute to the institutionalization of industrial recycling. Institutional feedback can be understood as a coordination of the changes that take place in formal and informal realities, and the success of such coordination defines the success and the scale of the overall institutional change.

In the *Introduction*, I made the point that, if particular models such as the circular economy or industrial ecology, do not properly integrate "our things" with other conceptualized aspects, we may consider them inadequate. By an "inadequate model," I mean a model that does not seem to fit its context. For example, we may consider industrial ecology suitable as a "practical tool" in the context of industrial planning, yet at the same time we may view it as unsuitable as a "strategic tool" in the context of market competition. To become a widely accepted ideology, a circular economy should be capable of coupling the economic interests of industry with ambitious recycling targets. In practice, a new ideology should be supported by policy incentives that value increased recycling. The cost-effectiveness of industrial businesses should result from the efficient circulation of materials and other resources. Only then could a new institutional setting, which would reflect the principles of a circular economy, slowly start to emerge. This may seem a far away vision, but we must remember that ideological and institutional changes do not happen overnight. And, we should keep in mind that overcoming each obstacle is a building block in a new institutional structure and economic system.

5.2 POLICY RECOMMENDATIONS

The policy recommendations that emerge from my research are twofold. These recommendations are my responses to the previously discussed lack of practical advice on the steps leading to circular economy. First, I will formulate three general policy recommendations that are applicable to the development and management of complex operational environments. Thereafter, I outline four more policy recommendations that are especially suitable to the development of industrial recycling. All recommendations are based on my empirical work and my theoretical considerations of institutional obstacles and feedback mechanisms in different situations.

5.2.1 GENERAL POLICY RECOMMENDATIONS

1. *The complexity of operational environments should be taken seriously in administration.* The governance of complex operational environments does not follow the logic of causality. In other words, it is constantly becoming more difficult to estimate the real-world implications of particular policy arrangements. Complex operational environment is in a state of continuous change, and therefore it is very challenging to influence different *functions* or *operations* within such an environment by means of more or less rigid policy instruments. Consequently, policy should focus on supporting the different forms of *agency*. Formal institutions should be crafted so that they enhance communication and transparency within the networks of actors.
2. *“Target points” of policy interventions should be specifically defined for different operational environments.* Focusing on functions and operations has meant that particular *activities* have traditionally been the targets of policy interventions. Often, however, the most efficient way of influencing an activity is to change the relationships and other circumstances of actors. In complex operational environments, it is very challenging to steer specific activities by means of policy interventions because the actors are usually better informed than the authority. Therefore, policy interventions should be targeted at strengthened interplay between formal and informal institutional realities. In practice, this would require a case-specific consideration of the “target points” of suitable policy interventions. Target points capable of mobilizing favorable developments can be found, for example, from formally defined rules that in a way or another delimit particular ways of doing things. For example, I have demonstrated how formal definitions of materials affect the treatment of industrial leftover materials. The definition process of materials was a good target point for policy intervention because a change in policy directly

improved the conditions related to material management in industrial companies.

3. *The role of institutional feedback should be recognized in the design of policy instruments.* Previous recommendations have suggested reconsidering the targets of policy interventions. Equally important, however, is reconsideration of the working logic of policy instruments. In complex systems, such as heavy industries, the development of manufacturing systems requires the actors' collaboration across the boundaries of expertise, and thus policy instruments should be designed so that they encourage collaboration. In previous sections, I have demonstrated how an advanced policy design becomes capable of triggering dialogical processes among the stakeholders of complex operational environments. Therefore, I recommend that novel policy instruments that are based on the logic of institutional feedback should be considered in different sectors of societies. The novelty of these kinds of instruments is that they allow the simultaneous development of both regulations and operational systems.

5.2.2 POLICY RECOMMENDATIONS FOR THE DEVELOPMENT OF INDUSTRIAL RECYCLING

1. *Responding to large-scale environmental threats requires more stringent environmental legislation.* Legislative changes – both at the international and the national levels – are effective ways of steering long-term industrial development. In the context of industrial recycling, this means establishing ambitious recycling targets in legislation. It is especially important that such legislation encourage all reasonable efforts at utilization of leftover materials and other resources, including so called “emissions.” When the targets are clear, it is easier to adjust other rule systems, such as practices and lower-level regulations, to suit them.
2. *Unnecessary regulatory categorization of critical issues should be stopped.* Inappropriate formal definitions of materials, waste, emissions, and different technologies cause many kinds of problems and misunderstandings in the development of industrial manufacturing. Therefore, regulation should avoid unnecessary categorization of the multidimensional issues that are critical to specific activities. It is especially important to consider carefully the legal treatment of issues whose comprehensive definition turns out to be contradictory, unclear, or biased. An efficient way of defining the critical issues is to allow for reciprocal and transparent reflection among the actors.

3. *Possibilities for policy experiments should be increased.* The ideas presented in the gradually tightening environmental legislation do not automatically fit into the belief systems of all relevant stakeholders of operational systems. Therefore, it is not wise to try and implant the new ideas forcefully into the existing lower-level regulations and established practices. A wiser strategy is to leave an opportunity for actors to consider and develop new ways of achieving the more ambitious targets. Significantly, this strategy allows new institutions “to rise up” from the operational knowledge of industrial actors. These new institutions probably make good candidates to replace existing lower-level regulations.
4. *Predictability of regulation needs to be increased.* The predictability of regulation is directly linked to the possibility of the long-term development of industrial manufacturing systems. Predictable regulation offers the chance for actors and other stakeholders to “steer their thinking” so that it better matches the regulations. In other words, predictability offers time to adapt to a constantly changing environment. In the development of heavy industries, predictable regulation also means enough time for innovation (see also Mickwitz, 2003). In contrast, unpredictable regulation often causes intolerable risks for industrial companies and thus prevents investments in the new processes and practices.

5.3 KNOWLEDGE CONTRIBUTION OF THE DISSERTATION

In industrial management today, complexity creates circumstances under which no single expert can know exactly how changes in the formal rule systems will influence the operational activities or what pressures the operational changes will generate back on the rule systems. In this dissertation, I have outlined a theoretical account of institutional feedback, which is the main knowledge contribution of this work and also its key result. I have argued that institutional feedback consists of two components: the production of appropriate knowledge, i.e., *knowledge networking*, and the management and maintenance of a network of actors who are central to the established aims, i.e., *network governance*. Institutional feedback is a phenomenon whose functions I have described both theoretically and empirically. As illustrated in Figure 7, institutional feedback can also be considered an analytical perspective or a framework. Figure 7 summarizes the layers and components of the analysis on which this dissertation is based and reminds the reader of some analytical tools that I have used in the evaluation of certain aspects of knowledge networking and network

governance. At the same time, this conceptualization sets a research agenda for analysts interested in studying the role or prospects of institutional feedback in particular situations.

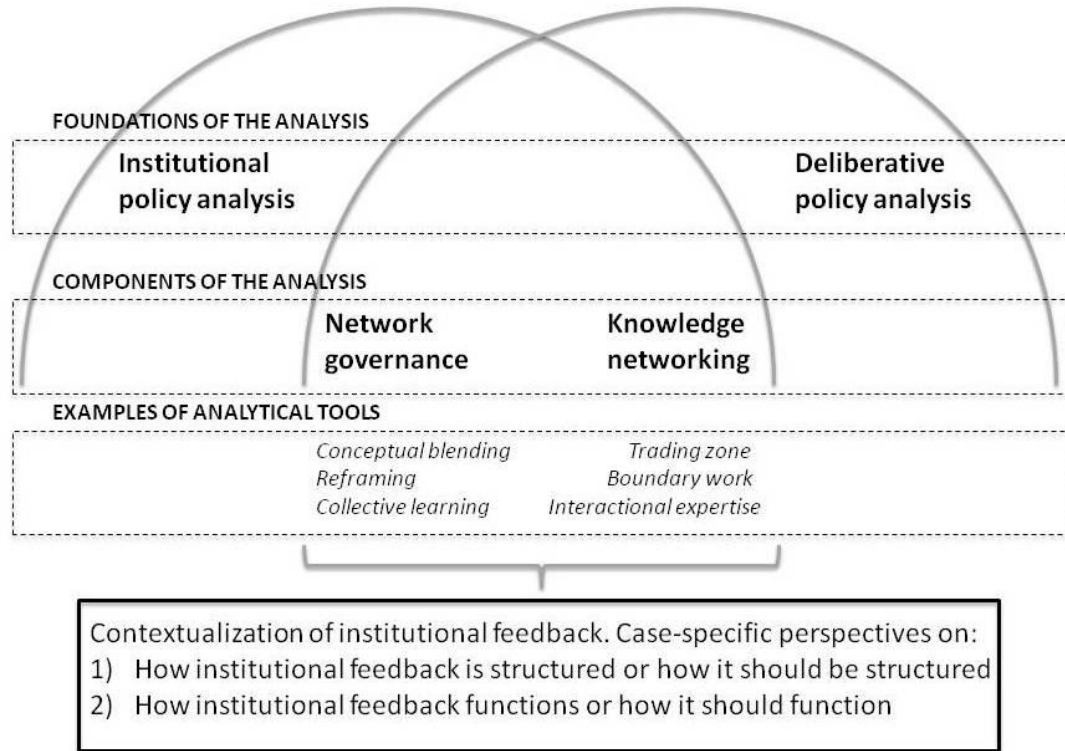


Figure 7. *Institutional feedback as an analytical framework.*

Recall (section 2.3.4) that an analysis of institutional feedback must cover both components – knowledge networking and network governance. The importance of components may vary, depending on the situation, but both are still needed in the evaluation of the structure and functions of the institutional feedback. This dissertation has demonstrated ways to identify, conceptualize, and study these two components. By means of a combined analysis of knowledge networking and network governance, it is possible to 1) launch a research process to identify different functions of institutional feedback (as a real-world phenomenon) and 2) contextualize the meaning of institutional feedback in particular situations (as a potential strategy to overcome obstacles) (see Figure 7). Once the functions and structure of a particular institutional feedback mechanism are identified and contextualized, it is possible to evaluate the effectiveness of the feedback. If the feedback mechanism is associated with a specific policy instrument, an analyst can ask whether this arrangement stimulates the dialogical process between institutional realities and if not, how the dialogue could be strengthened.

The existing theory of institutional dynamics suffers from the absence of a clear definition of institutional feedback. There are concepts that share certain similarities with my approach on institutional feedback, such as institutional interaction and interplay (e.g., Oberthür, 2009; Velázquez Gomar, 2014; Young, 2002, 2008), but those concepts fall short in their capacity to describe 1) the exact interconnections between changes in specific institutions operating in different institutional realities and 2) the meaning of institutional changes and interplay in relation to specific obstacles. By means of a clarified definition of institutional feedback, it is possible to investigate these issues analytically. Clarified terminology also contributes to theories that are higher in the level of abstraction of phenomena similar to institutional feedback, such as Douglas North's conceptualization of the interplay between belief systems and institutions (e.g., North, 2005, 23-64).

A theoretical account of institutional feedback facilitates the development of a research setting that simultaneously takes into account two things: 1) the long-term dialogical development of formal and informal institutional realities, and 2) the significance of specific short-term changes in particular institutions. Institutional feedback is not simply a theory-driven methodology, offering a description of the feedback under different circumstances. In its prescriptive dimension, the institutional feedback approach offers information about the ways in which feedback that accelerates favorable changes or the overcoming of practical problems can be constructed and facilitated (see Figure 7). A clarified notion of institutional feedback also emphasizes the need for appropriate coordination between regulatory development and operational-level activities. I hope that my notions contribute to the development of policy instruments and encourage policy-makers and industrial actors to consider their tools and practices from the perspective of feedback.

5.4 THE RELEVANCE OF INSTITUTIONAL FEEDBACK IN AN INDUSTRIAL CONTEXT

I have discussed the prospects of institutional change for increased industrial recycling. I have also pointed out some institutional obstacles that prevent or delay such change. The success of the institutionalization of industrial recycling depends on the success of the knowledge exchange and the coordination between the changes taking place in the formal and informal institutional realities. If the ideological content of change remains unfamiliar to a significant group of actors, then institutional change does not materialize. There is a risk that the recently introduced concept of a circular economy will face just such a downfall. In the optimal case, on the other hand, increased and focused communication between different actors can accelerate the institutional change and the development of industries toward improved resource management.

I have stressed that significant institutional change can only be achieved through ideological change. It is important to note that functional institutional feedback mechanisms are also “tools” of ideological change. Through different institutional feedback mechanisms, ideological entrepreneurs can communicate a new ideology to operational-level actors and other stakeholders, who in turn, can communicate their interpretation of the required changes back to the policy-makers. This is how institutional feedback mechanisms facilitate the interplay between formal and informal institutional realities. In the development of complex operational environments, maintenance of knowledge exchange networks becomes even more accentuated, because an interpretation of the ideology that facilitates a desired institutional change is not always assured. Indeed, the correct “translation” of expert knowledge between the different working cultures is an issue that all developers and managers of complex systems should pay increased attention to in the future.

I have also argued that the basic principles of a circular economy have the potential to serve as a cornerstone of a new ideology for industrial resource management. The successful implementation of such an ideology, however, requires a significant change in the stakeholders’ belief systems concerning the formal and informal rules of material management. In the development of policy instruments and practices for industrial management and for environmental governance in general, it is important to keep in mind that institutions and belief systems are closely intertwined with each other and also evolve hand in hand. Arild Vatn and Paul Vedeld (2012, 8) capture this idea in their elaboration on future directions of institutional theorization: “[a] solution could therefore be found in further development of institutional theory with a specific emphasis on how institutions influence motivations. Maybe people act according to plural motivations ... and institutions play a crucial role in forming or activating what type motivation will dominate.”

In an industrial context, ongoing reconsideration of the roles of the basic components of production systems is equally important. The dominant conception of an industrial unit serves as a representative example. Still today stakeholders in industrial management tend to consider single industrial units as the key components in the industrial manufacturing process. The consequence of such thinking is that actors mainly focus on the optimization of industrial processes within the units; similarly, authorities focus on the monitoring of single units or single industrial complexes at best. Nevertheless, according to principles of industrial ecology the focus should be shifted from units to networks of industries. This shift would have numerous implications for the management and the monitoring practices of industries. Other basic components whose suitability and performance should be constantly reconsidered include business models, value chains and partner organizations.

5.5 A NEED FOR FUTURE RESEARCH

The strength and the weakness of the circular economy concept is that it aims to describe a prevalent economic system. It is a strength because only a nuanced description of the prevalent economic system makes a plausible challenger. It is a weakness because it is very difficult to model all the relevant functions of an economic system. In this dissertation, I have discussed the institutional prospects of a circular economy in a heavy industrial context. Thus, research insights from this work can help promote the circular economy only in one sector. Similar empirical work is urgently needed, for example, in the fields of sustainable consumption, intelligent energy production and societal planning. Only experiences gathered from various fields will facilitate a constructive discussion on the circular economy as a widespread economic system and an alternative to the neoclassical model.

I especially encourage studies of institutional feedback mechanisms that would actively stimulate the collective learning processes among different groups of actors. My impression is that, by means of well-designed policy instruments which utilize the working logic of institutional feedback, it might be possible to influence the types of new knowledge being produced in different interactional situations. In other words, policy arrangements may enable the creation of information and practical advice which is needed for specific occasions, for example, in the development of different parts of complex systems. In the best-case scenario, institutional feedback mechanisms make it possible to address the right problems with the right tools. Identification of the right problems, however, is a task that requires novel methodologies whose development is one of the most pervasive challenges to the development and promotion of a circular economy.

Another and perhaps even more profound challenge is dealing with the right communication of the ideological content of the circular economy. It is critically important that *the message* of institutional change resonates with our beliefs, because otherwise it is more tempting to continue business as usual. In my view, the circular economy has a justified message which enables us to “seek our spiritual satisfaction” from somewhere beyond consumption.

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