INDUSTRIAL CHANGE TOWARDS ENVIRONMENTAL SUSTAINABILITY

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The case of chloroflourocarbons

Susanne Sweet

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Preface

This report is a result of a research project carried out at the Center for Marketing, Distribution and Industry Dynamics at the Economic Research Institute at the Stockholm School of Economics.

This volume is submitted as a doctor's thesis at the Stockholm School of Economics. As usual at the Economic Research Institute, the author has been entirely free to conduct and present her research in her own ways as an expression of her own ideas.

The institute is grateful for the financial support provided by the *Swedish Environmental Protection Agency, Tore Browalds Foundation, J.G. Richert's Foundation, Jan Wallanders & Tom Hedelius' Foundation* ,*MTC* (Marketing Technology Center) and *IFL* (Swedish Institute of Management). The Economic Research Institute warmly thank all for their generosity and support.

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Director of the Economic
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Acknowledgements

Reflecting on the long, winding, and often bumpy road leading up to the printing of this thesis, I would like to express my gratefulness to a number of people and organizations that helped me along the way.

First and foremost, I would like to thank Lars-Gunnar Mattsson who chaired my advisory committee. Thank you for not giving up on me and my thesis project and for sharing your knowledge on theory and thesis writing. The combination of support and threats worked to give me the courage to see the ending of this project as the start to something new.

Also, I thank my two other advisors, Bengt Stymne and Nils Brunsson, whose comments and suggestions helped me to be more precise in my writing and whose knowledge in the field of organizational theory and practice greatly informed my thinking. I also extend a special thank you to Staffan Hultén who acted as a supporting advisor and who gave new inspiration at a critical stage in my writing process.

The writing of this thesis could not have been possible without the input from people engaged in replacing CFCs. I interviewed and had many stimulating conversations with such people over the years for which I am grateful. A number provided much more time and knowledge than expected. I am very grateful to: Per Wennerström at *Electrolux* for devoting so much of his time in explaining to me about refrigerators and CFCs, in reading and editing my interview notes, as well as for taking me to the refrigerator plant at Mariestad; Bill Brox at *IVF* Gothenburg for patiently and with admirable authority telling me about the TRE-project; Ulrika Hagbarth at *Swedish EPA* for sharing her time and knowledge and providing me with the opportunity to participate on the panel for reviewing the Swedish implementation of the CFC phase out plan; Peter Pien, the *Swedish Plastic Association* for providing rich archival material in the Plastic Foam case; Ingrid Köckeritz, *SEI* and *Swedish EPA*, for sharing her insights on political processes in the Montreal Protocol negotiations. To Niel McCulloch &

Fiona Weir, *Friends of the Earth*, UK, and Tracy Hesslopp, *Greenpeace*, London for providing informative materials on CFCs.

My interest in doing research in the area of industry and the environment was kindled after a year at *University of Southern California*, USC, in Los Angeles. In my 40 minute daily commute to the university I was participating in creating, witnessing, and breathing the environmental problems caused by the use of automobiles. I also encountered several local environmentalists who tried to change things by volunteering their time, skills and compassion to instill environmental consciousness to other fellow humans. I am grateful to Gary Frazier at the Marketing Department, USC, for providing me with the opportunity of having these experiences and for giving me the opportunity to participate in a number of stimulating courses with their doctoral students. Financial support from the *Swedish-American Foundation* and *Carl Silfvén's Foundation* for my USC studies is gratefully acknowledged.

After returning to Sweden, MTC, *Marketing, Technology Center* provided me with initial funding for a project on industry and the environment. Göran Liljegren at MTC also put me in touch with Leif Strindberg at Electrolux who was interested in such research. The initial funding and the contacts at Electrolux provided the basis for the development of the topic of this thesis.

In addition to MTC´S start-up funding, financial support for this thesis has been provided from the *Swedish Environmental Protection Agency, Tore Browalds Foundation, J.G. Richert's Foundation*, and *IFL* (Institutet för Högre Företagsledning) and is gratefully acknowledged. An extra thank you to*Jan Wallanders & Tom Hedelius' Foundation* who supported my participation at three international research conferences. *The Greening of Industry Network, GIN,* annual conferences have been particularly important for me as an arena for discussing and exchanging ideas.

My colleagues and friends at my department at Stockholm School of Economics have criticized and supported earlier version of this thesis.

Thank you everyone in the Marketing Area! Without your presence it would have been more difficult and I would have felt very much on my own. Also an extra thank you to Bengt Jacobsson, SCORE, who gave valuable feedback on the "final seminar", and to Per Andersson who, with Staffan Hultén, gave input on the first "final" manuscript.

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Two people have been important in the last stages of the completion of this thesis. Ragnhild Alexandersson whose creativity made the cover of this thesis look interesting enough for the coffee-table. George Cook who, with patience, skill and a Scotsman's humor, scrutinized and improved my English text during the last few weeks. Thank you Ragnhild and George. You are both people with great skill and professionalism.

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My last thanks and thoughts go to my family. To my father Rolf, grandmother Anna-Lisa, and Brynolf, who would have enjoyed this day had they still been with us. I miss them. To my mother Aina and my siblings, Anne and Patrik, who have been supportive in times of frustration and joy. To Dave and Dot who willingly share love and wisdom. To Patrick who makes it all worthwhile.

Susanne Sweet
Stockholm, March 29, 2000

CONTENTS

PART I

SUSTAINABLE DEVELOPMENT AND INDUSTRIAL CHANGE

Part one constitutes the two first chapters of the thesis. The first chapter introduces the background to the study and the research problem and purpose. Chapter two consists of two parts. The first part is a brief overview of ecological problems in society and of some general approaches in solving them. The second part summarizes recent literature in business administration that address issues of ecological problems and industrial change and concludes with a choice of perspective for this study.

Chapter 1. Background and purpose

Our point of departure is the interplay between industrial and broader societal issues. Increasing amounts of social energy and resources are being devoted to ecological problems and issues associated with the expansion of ecological hazards that accompany increased production and consumption stemming from industrialization and global population growth. In recent decades, society has become more diligent in recognizing and identifying such hazards. As a consequence, ecological and environmental protection has emerged as an important item on both the political and industrial agendas. New laws, regulations, institutions, institutional measures as well as industrial, organizational and public voluntary activities to protect the environment have been developed all over the world over the last decades. These movements have become manifest in an almost worldwide commitment to ecological issues and the acceptance of the principle of sustainability[1] as a ground rule for future economic, ecological, and social

[1] Although the term, used in connection with economic, social and ecological balance and justice, was first introduced in 1987 by the Bruntland Commission on sustainable development, it was not until the

development as seen at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992[2].

Finding solutions to immediate environmental and ecological problems and to future resource scarcity might hold profound implications for sustaining life on earth. To a great extent industry represents both a substantial part of such problems and also represents sources of promising solutions to them. Thus, it is important to understand the dynamics involved in industrial processes working for and against sustainability. A greater understanding of forces that impede industrial change or propel it towards sustainable practices will enhance both industrial actors' and policy-makers' capacity to better design policies and activities aimed at changing common industrial society routines.

Choice of perspective in this study

This thesis presents a description and analysis of an industrial change process that took place as a result of an almost worldwide pressure to ban the use of a chemical compound, Chloroflourocarbons, CFC's. We will explore the issues of change both empirically and theoretically to gain a larger understanding of change processes towards sustainability in industrial systems. Our domain is the study of the process of technological, industrial, and social/institutional change in relation to one of the most severe threats to our ecosystem: the depletion of the ozone layer and the resulting increase in the amount of dangerous solar radiation reaching Earth.

We address the case of one particular and critical innovation, Chloroflourocarbons (CFCs), and the industrial change processes that followed as a result of social pressures to bring about a ban on their (CFCs)

conference in Rio de Janeiro that it was widely integrated and used in policy discussions. Sustainability was defined by the Bruntland Commission as "The needs of the present without compromising the ability of future generations to meet their own needs"(WCED, 1987).

[2] For a discussion on the principle of sustainability see chapter 4.

use some 70 years after their introduction. Major industrial and consumer product manufacturing processes and products around the world had come to rely on these chemical compounds. The processes by which their ban and substitution came about hold implications for understanding how institutional, technological and social elements interact in the innovation and change process as well as its governance and how it is nurtured. The thesis focuses primarily on the interactive nature of technological, institutional, and organizational systems and processes.

We further focus on the Swedish regulation of Chloroflourocarbons (CFCs) and the resulting industrial change processes, patterns and solutions. The case is embedded, or grounded, in three industrial networks that responded to the regulations. The study investigates the change patterns found when industrial actors worked on finding substitutes for the CFC compounds used as: (a) a blowing agent in insulation and a cooling agent in refrigerators; (b) a cleanser of electronic equipment; and (c) a blowing agent in the manufacture of flexible polyurethane foam. Taken together, these application areas offer a macro study of Swedish actors' ability to coordinate efforts and mobilize resources to solve a *specific* environmental problem.

The choice of perspective in this study is based on the notion that we need more accurate and deeper accounts of structural and behavioral patterns and processes of industrial change to be able to influence change towards sustainable development. This study captures the interdependencies and complexities inherent in the industrial systems and processes, and analyzes how they relate to change processes and outcomes in the case of CFCs. Accounts of the embedded nature of the institutional, organizational and technological environments of the actors constitute a context in which industrial processes and behaviors towards more ecologically-suited activities and products can be highlighted, analyzed and understood.

In traditional economic theory[3], pollution has been treated as external effects of production and consumption. Economic actors are assumed to consider expected costs and utility before deciding on levels of production, consumption, and investments. Correction of the minus side of the market, for example welfare losses due to pollution, is approached by cost-benefit measures like efficiency pricing, substitution, and/or hypothetical compensation. Favored proposed policy instruments in this research tradition are pollution taxes, emission trading/pollution rights, impositions of property rights, and elimination of subsidies (Turner, 1993).

However, the costs for environmental pollution have not been easy to measure and integrate in existing business models and practices in spite of the development of economic and regulatory models aimed at reducing or putting a halt to negative externalities. In economic research, the suggested models and policies aiming at defining control systems to influence the industrial impact on the environment were based on assumptions of actors making rational choices based on perfect information. The assumptions of the individual actors and their behavior were then aggregated to predictions of industrial change on the macro - or societal - level. Some of the proposed tools have been very successful in reducing pollution, while others have failed to have the intended impact. One failure worldwide, for example, is the effort to significantly reduce total usage levels of fossil fuels, especially in private transportation by car. The fuel usage per kilometer has been reduced by technical advancements but at the same time driving has increased as well as engine size both leading to increased emissions (U.S. EPA, 1999).

Interest in the natural environment is a relatively new phenomenon in business studies. One reason for this could be that a strong technological focus on solving (specific) environmental problems has directed the

[3] i.e. neo-classical economic theory, where natural resources are treated as a form of capital and are subject to the principle of perfect substitutability.

research towards the engineering sciences - the single largest receiver of environmental research funding (Wolff & Ytterhus, 1995).

In addition to technological solutions management tools like environmental performance assessments and auditing have also provided a major research topic for the engineering sciences. Environmental management itself has recently emerged as a field within business administration. The early focus was often normative, similar to the economic and engineering sciences, aimed at controlling industrial environmental behavior by means of various control measures and strategies. The "single" firm was often the target of strategic literature that basically added the notion of pollution (or public awareness of such a problem) as an external factor to integrate in the analysis of business opportunities or threats. Later developments in the field show a greater interest at the consumer, firm and industry levels in understanding and explaining the underlying dynamics involved in the re-orientation towards a sustainable society.

Change towards sustainable systems is far from problem-free and neither is its study. Some 50 years of research and study devoted to business administration, sociology, organization, management, and economics confirms that effectively changing established technological and organizational systems requires an understanding of normative and social processes associated with technological and economic dynamics. Thus, one way to understand change and the patterns with which we approach ecological problems is to address and tie our definition of the technological elements and their ultimate adaptation to the social systems within which technological systems and environmental problems are embedded. Indeed, to not do so would be tantamount to treating what could possibly be the most critical ecological problem of our time, namely CFCs, with insufficient diligence.

Purpose

The contribution or purpose of this study, in its broadest possible sense, is to investigate, analyze and impart knowledge about change processes undergone and their outcomes in the domain or area of solving or minimizing ecological problems. Our focus, of course, is sharpened so as to develop understanding of change processes in more clearly defined settings -- in our case, industrial settings -- since they are ubiquitous and represent major sources of ecological problems and opportunities for change. With ubiquity often comes variety. Industrial settings are studied and understood as functional systems with purposes and dynamics which either vary widely or appear quite similar, depending on one's level of analysis as well as the perspective of the viewer.

From the standpoint of understanding change processes involved in solving or minimizing ecological problems, this study takes as its point of departure the viewpoint that there are processes influencing change at multiple levels within all industrial settings. On the technological or productions system level there are path-dependencies shaping the outcome of a change process. Similarly, on the organizational and industry level, the established relationships between actors and their knowledge, needs, and wants influence the change process. Finally, on the institutional and societal level the change processes and outcomes are strongly influenced by institutional structures and processes inherent in the cultural system of which industry is a part.

As such, a primary purpose of our study is to examine technological, relational and institutional influence on industrial environmental change at multiple levels of analysis. That is, our effort is to clarify why, at higher levels of analysis, the outcomes of attempts to solve or minimize ecological problems appear similar - and indeed are often desired to be similar, as in cases where a particular behavior is intended to be stopped, like using a harmful substance, destroying a particular resource, or endangering a species, etc. - while at lower levels of analysis there exists variety in the coordinating mechanisms and processes by which such outcomes are attained. We believe that such a contribution to understanding change in this context can inform efforts to change harmful environmental behaviors on the part of individual actors, organizations or networks of organizations.

We also believe that change only has meaning in relation to stability. Just as there are forces for change there exist forces for stability. Much of any change process can be understood by a thorough examination of both stabilizing and dynamic forces in the industrial system. For example by studying behaviors, structures and processes in technological and organizational systems. The industrial system might not actually resist "change" per se, but the success of a targeted change effort in all likelihood will be influenced by existing forces already at work. As such, this study will examine restraining and facilitating factors and sources at work at multiple levels of analysis so as to provide an understanding of some of the sources of variety in change processes observed.

The CFC-study and its organization

During the research project, certain alternatives have been chosen that should be mentioned since, in retrospect, the choices made have been crucial for the pattern of the continuation of the study and its outcomes.

First, the choice of ecological problem to study: the depletion of the ozone layer - believed to be one of the most severe ecological threats to life on Earth. Due to the severity and global and long-term scope of the problem, it poses an interesting global challenge for humankind to meet. For this researcher, how the problem was discovered, analyzed, and the steps taken to solve it were equally interesting in that the process involved extensive interactions and coordination of efforts over a long period in time between researchers, industries, non-governmental organizations and policymakers from many countries. All countries who were members of United Nations in 1987 either subscribed in principle to or participated in the development of the international protocol (the Montreal Protocol) for the phasing out of what is believed to be the leading cause of the problem, the emission of Chloroflourocarbons, CFCs.

In addition to the international processes, the Swedish phase-out plan was the result of a new way of negotiating and implementing environmental regulation in Sweden. Industry actors were invited to actively participate in negotiations and discussions of the perceived problem and possible solutions. The resulting time table for phasing out the chemical substance was detailed for different usage areas according to the perceived difficulty (as argued by key actors) to find alternatives. Earlier environmental regulations were most often implemented by a "top-down" approach, not actively involving industry in the regulation process.

Secondly, once the choice of ecological problem and environmental regulation had been resolved, the type of study was chosen. Fairly early it had been decided that the case study approach would be the most suitable in studying industrial ecological change. At the time few studies had been made of industries and how they handled pressures to adapt to ecological demands. Being part of a research institution and network of researchers, with a particular interest in industrial processes and change, was instrumental in the choice of theoretical issues and frameworks to focus on. In addition to the already established interest in theories on the functioning of industrial networks and markets, a graduate course in International Relations at the University of Southern California, Los Angeles, aroused an interest in the interplay between governmental and industrial actors and processes. At the same time another inspirational course in Organizational Theory planted the seed that institutional theory should be relevant to the study of inter-organizational problems.

Thus, the problem - the third choice - was rather what part of the CFC network to study. After reviewing governmental and industry reports, the choice was made to focus on three applications of CFCs based on variation in three criteria: 1) technological complexity or level of interconnectedness in relation to CFCs and the application of which it was a part (systems ranging from highly to marginally dependent on CFCs for their functioning); 2) size and scope of the actors involved in the production of different applications (large - small firms, international - national/local, homogeneous - heterogeneous products); 3) total amount of CFCs used.

To reflect the consumption levels of CFCs the initial criteria was to choose the three largest usage areas of CFCs in Sweden. Refrigeration was overwhelmingly the largest, followed by electronics and flexible foams. The selection strategy used also revealed variation in industrial characteristics as well.

The firms in the refrigeration business are few, large and international with relatively homogeneous products. Their suppliers are also international in scope and relatively few - some of them even larger than the refrigeration firms, i.e. chemical firms. CFCs were crucial for the functioning of the product, as a refrigerant and as a blowing aid in insulation foams and highly interconnected to other parts of the refrigeration product and production systems.

The electronic firms are many, even if we only focus on Sweden, with very heterogeneous products. Company sizes in the electronic industry vary from the very large international firms, Ericsson for example, to small single owner shops. CFCs were not integrated and not crucial for the functioning of the electronic application, but rather were used in a stage in the production process.

Flexible foam *applications* are many but *producers* are few: two in number. CFC use in flexible foams is also a very regional/local application due to bulky transportation of the ready-for-usage foam products. In this network of actors, the customers are powerful and large in relation to the foam manufacturers. CFCs were interconnected with other parts of the application but not crucial for its functioning.

The most complex application in terms of difficulties in implementing new solutions and the amount of technological interdependencies extant in the relations and system is in the refrigeration case and therefore a choice was made to closely follow a focal actor's process in replacing CFCs. It was also an opportunity to follow the change process, since it was the only area in which CFCs had not been phased-out at the time of the study. CFC usage as a cleaning agent in Electronics and as a blowing agent in flexible foams had already been phased-out by 1 January, 1991.

In the Electronics' case, the process to find solutions was driven by the TRE-project, based at a research and development organization owned by the electronics industry, rather than by individual firms. The project was a Nordic project supported by industry and the Nordic Council. After interviews with Ericsson and the Federation of Swedish Industry Association, a choice was made to primarily focus on the activities connected to this project rather than on individual firms since the change activities in firms were entirely based on the participation in or implementation of results from the TRE-project.

In the Flexible Foam case, the two actors on the Swedish market were included. Their process was also related to coordination of activities in industry - or with competitors - while efforts to find new information on their change efforts eventually focused on the industry association, Plastförbundet.

To find information on the change process in industry, a mixture of interviews and a collection of written information was used (see list of references in chapter 5). First, written information was gathered to get an overview of the problems and issues at hand. Those sources included governmental reports, including the proposal to regulate and the final phase-out plan, reports provided by industry, national and international business journals and reports from environmental organizations. Then the Refrigeration study was initiated primarily at Electrolux. Interviews of key personnel were performed over a period of 3 years, with people directly and indirectly involved with the project. Several visits to the R&D department at Electrolux's Corporate Headquarters and a visit to the refrigeration plant in Mariestad were also undertaken to get a richer picture of the change processes and productions system realities. Head Office archival material on Electrolux, the development of refrigeration at Electrolux, and annual reports dating back to the 1920s were accessed.

Electrolux apart, the majority of the other refrigeration manufacturers were interviewed about their CFC work at an industry fair in Germany. As there had been extensive information interchanges regarding possible alternatives and also formal cooperative projects between the manufacturers to test alternatives, it became clear that it was important to include the other manufacturers in this network study. Interviews were also undertaken with important (with regard to the CFC-project) suppliers. They included compressor manufacturers, chemical manufacturers and chemical industry associations.

In the cases of electronics and flexible foams, interviews were also conducted with people from management and operations involved in the CFC-decision and change processes. Written sources have been important in these cases. The Plastic Manufacturers Association gave access to all protocols from the meetings between the flexible foam manufacturers, where the issues with respect to strategies and problems involved in phasing out CFCs in the case of flexible foam were well documented. The Plastic Manufacturers Association played an important part in the case of phasing out CFCs from the flexible foam products. The association created an arena where competing firms could meet and make strategic decisions with regard to the CFCs. Surveys and evaluations made by the Swedish

EPA have also contributed with information in the flexible foam and electronics cases.

Another important aspect of this study was the inclusion of the governmental, or regulatory and political, relationships in the network. Information on government processes has been drawn from several sources, from research literature, reports, information material, and meeting notes from UNEP, the Swedish Government, and Swedish Environmental Protection Agency and from several interviews with officials directly involved in the CFC regulation and evaluation processes. And lastly, it helped that this researcher was also one of the actors, participating on an expert board at the Swedish EPA. Accordingly, in numerous meetings and discussions with Swedish EPA members the perspectives on the processes of evaluating the process and outcome of the Swedish CFC phase-out were much enhanced by information gained informally and tacitly regarding processes, outcomes, and their relationship in practice.

Structure and content of the thesis

I. Sustainable development and industrial change

The first part juxtapositions the thesis relative to other studies of business and the environment. In the first chapter a short background to the focus of the study, purpose, and structure of the thesis is presented, and a discussion on how the study has been organized and the choices made during its course.

The second chapter provides a general background to ecological problems and societal attempts to solve them as well as an anecdotal overview of the industrial actions and responses to demands in finding environmental sustainable solutions. In particular emphasis is put on the organization of resources and activities and the development of technologies and strategies in industry.

II. Theoretical aspects of industrial change:

In part II a review of theoretical perspectives is presented which will contribute to our knowledge concerning industrial change and processes of change. Two perspectives on change are outlined: the role of the inter-organizational and technological interdependencies in industrial change and the role of institutional pressures in shaping processes and outcomes. The last chapter in part II outlines the analytical framework that will be presented to analyze the case of Chloroflourocarbons.

III. Change processes towards environmentally sustainable systems

Part III presents the case of Chloroflourocarbons. The chapter starts with a general background to the underlying environmental problem followed by a description of the political process leading up to the international and national regulations banning the use of CFCs. Then three different industrial CFC applications are described in terms of responses, actions, and processes of change leading to a total phase-out of the chemical. The applications are related to three different uses and areas of use: as a refrigerant and blowing agent (Refrigeration); as a solvent (Electronics); and as a blowing agent in soft foams (Flexible foams).

IV. Analysis & concluding remarks

In part IV our analyses and conclusions of the chloroflourocarbon case are presented in chapter six. The influences of organizational processes and structural interdependencies, the influences of technological interdependencies, as well as of normative meaning systems and institutional patterns are explored for each of the three CFC applications.

Chapter seven reflects on the theoretical and empirical results of this study. In terms of theory, suggestions are made to integrate institutional and network theoretical perspectives when studying complex phenomena such as sustainable development and industrial change. Understanding industrial ecological change is a multifaceted interplay between technological, organizational and normative processes and structures, not isolated to the study of single organizations or to the structure of industrial actors' interactive relationship alone. Therefore, we suggest the inclusion of analysis on several levels of inquiry: the actors and their networks, including the meaning system,[4] of which they are a part, and the technology related to the product and production systems.

The chapter concludes with a discussion of the implications for the study of industry and ecological change and gives suggestions for future research. Some implications for environmental and industrial policy are also given.

[4] In organization literature meaning systems are often referred to in the context of shared organizational or inter-organizational culture, traditions and norms. See chapter 3 for more on meaning systems.

Chapter Two: Ecological problems and industrial change

Ecological threats and approaches to solve them

Ecological problems and industrial activities have had an indisputable parallel development. Ever since the beginning of the industrial era solving and managing environmental problems has demanded increasing amounts of societal energy and resources. Early environmental problems focused on scarcity of natural resources like food and wood to support growing populations and raw materials at reasonable prices to support industrial development and economic growth.

Rapid expansion of industrialization and urbanization was followed by extensive use of some natural resources, for example forests. In the beginning of industrialization timber was a major input in many industrial activities as the source of energy, for example, or as a raw material in construction (Swedish Forestry Industry Association, 1997).

In the late 1800s several regions and countries experienced shortages of wood due to ruthless felling. These regions also took notice of the negative impact such activity had on wildlife. In the U.S.A. natural conservationists gained influence and as a result social and political programs to save wilderness and wildlife were enacted which, for example, resulted in the introduction of National Parks. In Scandinavia similar patterns could be seen. The large forests of the Scandinavian countries have been one of the most important natural resources upon which economic prosperity and wealth have been built and maintained in the Nordic region of Europe[1]. With industrialization the usage of timber increased while the Scandinavian countries experienced a shortage of wood supplies in many areas by the end of the nineteenth century. The forests had diminished and regenerated poorly due to a combination of brutal logging and centuries of slash-and-burn agriculture. The largest user of wood in Sweden was the iron industry who used it in the production process of iron ore.

[1] The Scandinavian forest industry and its development has also been described in Östlund & Roome, 1998.

Due to diminishing forests, Scandinavian countries began to take action in the early twentieth century to halt the devastation. Preservation was seen as the solution and silvicultural laws were enacted making the forest-owners responsible for ensuring that forests were tended with due regard to their long-term sustainability. At about the same time, a movement to re-plant trees began in areas laid waste. Many volunteers participated in this effort to "re-build" the Scandinavian forests and as a result the forests recovered. Today, two thirds of sparsely populated Sweden and Finland and a little more than one third of Norway are tree covered. This constitutes more than half of Europe's forests making the Nordic countries an important supplier of wood and wood products to the European Continent and its large population (Swedish Forest Industry Association, 1997).

However, even if the net growth of the forests in this region has been positive, very little of the virgin forest remains. New types of trees with faster and higher yields more suitable for large-scale forestry entered the Nordic flora and together with new logging methods they have had a profound impact on the eco-systems in this region. Clear-cut methods left large areas without trees to support animal and plant life and created large "wounds" in the landscape with reduced bio-diversity as a consequence.

While the late 19th and early 20th century environmental problems and concerns focused on resource scarcity and, as such, were translated into policies regarding resource conservation and preservation of animal and plant life, new problems soon surfaced that related to pollution created by and in the production processes. The negative influence on workers' health was an issue that received attention and new laws and safety regulations to protect workers from harmful and dangerous job activities were integrated into the labor laws that emerged in the early to mid 20th century.

In the 1960s the effects of increased consumption and industrial production started to be acutely visible on land, in water and air. One of the most influential books that epitomized many people's experience of nature's degradation around them was Rachel Carson's book Silent Spring, first published in 1962. Her story of the silent spring in the mid-American town, supported by research into the use of synthetic chemicals in farming and of the environmental damage that would follow the indiscriminate use of chemical pesticides and insecticides on the land, undoubtedly inspired several generations of policy makers, environmentalists and scientists. With her book environmental issues gained momentum and a new era in environmental protection emerged.

In the 1960s focus was mainly on emissions to water and air that caused local and regional environmental problems. Many countries, for example Sweden and the U.S.A., developed institutions that would operatively help develop protective measures, supervise environmental laws, and stimulate research on environmental protection. The growing interest of the public and increased activities around environmental protection spurred the development of regulatory measures for outlets to air and water. For example, the early environmental regulation in the U.S.A. was directed at industries responsible for causing unacceptable levels of air and water pollution while relatively little attention was given to other types of pollution like solid waste (Henion, 1978). The industrial response was often based on assessments of available technology and on the investment cycle and at which point the existing equipment and machinery were. However, over time industry was spurred to develop and invest in technology aimed at lesser impact on the local environment and many of the local environmental problems were greatly ameliorated.

The first real global environmental issue surfaced with the energy crisis in the 1970s, the industrialized countries' dependence on and use of fossil fuels, a non-renewable resource. The crisis became a starting point for public programs and campaigns on energy-saving, research into alternative energy sources, and industrial development and re-design towards more energy efficient products and production processes.

The trend to enlarge the perspective to a more global or system-wide perspective was strengthened in the 1980s and 1990s. Issues of conservation and use of genetic resources and biological diversity, global warming, the fate of indigenous people, equity in international trade, and climatic change, etc., were hotly debated and discussed on a scale never witnessed before. Initial organizational response in the 1980s was to meet conservation demands. For example, investments were made in building systems for the re-cycling of paper with resulting new technological development in adapting products to the re-cycled materials. As a result a number of new products based on re-cycled paper quickly gained market shares from products solely based on virgin wood fiber.

Managing or finding solutions to some of the environmental threats are critical to sustaining life on earth while other environmental problems are important but less of an immediate threat. The recycling of paper products, for example, poses a long term challenge for society but its slow or less than immediate application and total implementation could not be termed critical. However, there is a sufficient consensus of opinion within many social institutions that the destruction of the ozone layer of the earth's stratosphere is critical.

The governance of environmental problems in Sweden

Unfortunately, successfully addressing or solving ecological problems is quite complex. Since the 1960s ecological problems have been the focus of governmental interventions. Reports and studies of the decline in air and water quality during the 1960's and 1970's, initiated an evolution of public policies and regulations to get a grasp on the problems. The first phase of ecological policies, programs, and regulations focused on emissions and discharges out of smokestacks, sewers, and industrial outlets and took the form of required standards or limitations of polluting behavior. Many of these activities were quite successful in reducing harmful emissions to air, land, and water. For example, the Swedish originating emissions of sulfur dioxide have been reduced by 70% since the early 1970s (Prop. 1987/88:85). Yet, many of the threats to the ecosystem are of a global character limiting the effect of national programs. For example, the total fall-out of sulfur dioxide over Sweden was not reduced by more than around 35% during the same period (ibid.).

During the 1980's, several larger environmental incidents heightened public awareness of the vulnerability of the ecosystem. For example, the Exxon oil spill off the coast of Alaska; the deaths of seals in Sweden and Norway; and the discovery of a hole in the ozone layer over the Antarctic. With increased awareness came renewed demands for the finding of solutions to environmental hazards.

In the late 1980s criticism grew against environmental policies in Sweden. The early Swedish environmental protections were to a large degree directed by the 1969 Environmental Protection Law. They were based on principles of property law and regulated one property's influence on the other. The law mandated actions when they were "environmentally motivated, technically possible, and economically reasonable" (Environmental Protection Law 1969:387)). Neither the problems caused by the consumption of products nor the harm caused by the extraction of resources were covered by the law. Also, the specialty laws, regulations, emission standards, and organizational control mechanisms had grown in number but were considered complex, unclear, not integrated (even conflicting), and mainly locally focused. Also, the penalties for violation against the laws and regulations were few and relatively mild.

The complexity of the environmental laws and the renewed interest in environmental protection instigated the Swedish government to investigate other approaches to organize and manage environmental issues. As a result, a new governmental department was created in 1987 with responsibility for organizing and coordinating environmental protection in Sweden. In 1987 the Minister of Environment and Energy, Birgitta Dahl, commissioned an investigation of existing environmental laws and policies which resulted in a proposition to re-organize the environmental practices (Prop. 1987/88:85). A number of new policies were created and the different regulations were integrated under the same Act, "Miljöbalk".

These events started the second phase in environmental policy development in Sweden. A greater focus was placed on the products and their environmental impact during production and consumption. Policies that emphasized producer-responsibility to reduce the harm of product as well as consumer-responsibility to choose environmentally adapted products. For example, the Chemical Products Act has a principle of substitution mandating a producer to choose the least environmentally harmful chemical alternative if technically and economically possible. And the consumers are supported by, for example, the development of eco-labeling systems that certify the product as managed in an environmentally responsible manner.

Change of focus: from "end-of -pipe" to sustainable development

The third phase in environmental protection has emerged as a new perspective: that of sustainable development. Sustainability became the guiding concept - or principle - for the protection of eco-systems and it was promoted in the Bruntland Commission report on environment and development[2]. As noted in chapter 1, sustainable development has been defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". The concept also influenced a fundamental change of focus on the human impact on nature: from our impact on land, water and air to our impact on the whole ecological system. Sustainable development as presented in the Bruntland Commision's report entails an array of regulations, control measures, and management systems developed to capture, monitor and analyze the impact of human activity on the entire eco-system. The perspective has gained increasing acceptance and the Swedish government has also declared its goal to realize the ecologically sustainable industrial society (Lönnroth, 1995).

The last decade's development gradually changed the focus on industrial environmental impact from "end-of-pipe" to products and their impact on the ecosystem. Products that were considered harmful to the environment were consumer boycotted, putting pressure on manufacturers to change their products. Policy makers instigated new laws concerning producer

[2] A United Nation sponsored commission assigned to investigate the state of the environments in relation to economic and human development issues.

responsibility to recycle their products. Industry developed models and tools to help them assess the environmental impact of their products and initiated re-cycling systems. And eco-labeling of products was launched. The first eco-label in Sweden was introduced in the early 1990s and was a result of a cooperative project between retailers and an environmental protection organization, SNF[3], and was later followed by several others.

Changing complex systems to solve environmental threats

How then is industry acting and responding to the demands on sustainable development? How do existing environmental problems get solved and how does industry design for the avoidance of future threats? Many ecological problems may be theoretically "solved" through an adequate adaptation or use of technology. Recycling paper products is complex but one can argue that the science and technology involved are not nearly as complex as, for example, the maintenance and, in the future possible, recycling of communication satellites. In fact, most of the technology and processes for recycling paper products are available and in use. However, building and agreeing on systems for recycling, raising the public awareness and gaining its participation to fully sustain production and market systems of recyclable paper products has yet to be achieved.

The difficulties often multiply when we turn to more critical problems such as the disposal of nuclear waste. The technologies (and substances) involved in fueling nuclear reactors are certainly more volatile and complex than those involved in recycling paper products, for example, and, as such, adapting solutions to managing nuclear waste is more complex. However, as with recycling paper the difficulties in adapting technological solutions multiply when we recognize that the ecological problems and the perception of their solutions in themselves are socially defined and they are embedded in social as well as technological systems.

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[3] Svenska Naturskyddsföreningen. The eco-label, shaped like a swallow, was first introduced for chemical products used in households.

We have alternative technologies for power production but they are hotly debated particularly as to whether the benefits in adopting these alternatives warrant their cost.

Turning to another ecological problem we find a circumstance were the technology involved is not as complex (as nuclear waste management) but where there is widespread agreement that the ecological problem involved is ultimately critical. The culprit is the release of CFCs into the atmosphere. CFCs are a relatively simple group of compounds that have been available since the 1930s. Their release into the atmosphere has been theoretically linked to the destruction of the ozone layer - without which solar radiation would destroy most life on earth. Because of these implications societal institutions (scientific, environmental, media, and public opinion) succeeded in defining and bringing the problem of the depleting ozone layer to the top of the political agenda on a global basis. This resulted in an attack on the chemicals involved, CFCs, culminating with an almost worldwide agreement to ban their production and use before the year 2000.

The first time the relationship between the release of CFCs and the depletion of the ozone layer reached a wider public awareness was in the early 1970s. More than twenty-five years will have elapsed before we as a society have adapted and stopped our use of a *relatively simple compound.* This compound is not critical to any life systems nor are any societies critically dependent upon it. Many of our environmental problems are of the same nature. We know that many substances, products, processes, and behaviors are not in line with a sustainable environment but the systemic effects of established complex technologies, organization of production and marketing systems, as well as political and behavioral systems, govern and limit our strategies to solve them. Thus, studies of interdependencies between and inertia in institutional, organizational and technological systems can contribute to our understanding of the patterns of industry response to ecological problems.

Society, business and the environment - approaches to environmental problems

Ecology[4] entered the field of modern science with Charles Darwin and his generation. These early "naturalists" explored the relationships between diverse natural phenomena, suggesting their common origins and hidden connections (Gancher, 1991). One insight that emerged from this research was the realization that the existence and sustainability of the natural system was dependent upon the inter-relationships between its parts.

By the end of the 19th century an articulation and broadening of these ecological ideas into social and ethical domains emerged with the formulation of *conservation* and *preservation* approaches in scientific inquiry. The scientific developments in these fields of conservation and preservation were later paralleled with a social environmental movement that had grown very large by the 1960s: "now many social ills were recognized as related to the degradation of nature" (Gancher, 1991).

Ecological problems, studies of them, and issues raised by them occurred less frequently in the social sciences literature than in environmental sciences. It was not until the 1960's that research in the area of environmental economics was established on a broad scale. In Sweden, Professor Eric Dahmén was one who raised early issues relating to industrial activities and protection of the natural environment. In an influential booklet[5] published in 1968, he pointed out the weaknesses in economic theory in understanding and solving environmental problems caused by industrial firms. The costs of negative externalities caused by industrial pollution were seldom borne by the polluting firm and the societal costs for a polluted environment could not easily be integrated into corporate accounting systems. "Cost accounting stops at the smoke-pipes, factory gates, tail-pipes, sewer outlets, etc. and no one is forcing the producers on a regular basis to

[4] In the natural sciences, ecology is generally regarded as "the branch of biology that deals with the relations between living organisms and their environment". In sociology, ecology generally refers to the study of the relationship and adjustment of human groups to their geographical environment (Webster, 1980).

extend it further"[6] (Dahmén, 1968). He warned of the future consequences if such pollution was not taken seriously by industry and consumers and argued for including the societal costs for pollution in the price of products and services, an argument that is gaining a following and is further developed by Bergman, (1993), for example, in a recent publication.

The economic theories that developed focused mainly on external effects and methods of solving them. For example, environmental fees, taxes, regulations, and trade in pollution rights are methods that were developed by economists and used by policymakers to handle pollution from production processes and products (Mäler, 1980; 1984).

Since neo-classical economic theory failed to explain why firms can become motivated to engage in improving their environmental behavior in the absence of regulations, fees, or other governing laws or policies, economic theorists are currently trying to develop other approaches to gain a better understanding of industrial behavior. Bergman (1995), for example, has tried to model the environmental behavior of firms by applying the alternative cost method, in light of recently observed developments in practice with product and process improvements motivated by consumer preferences and a generally increased environmental awareness. He argues that the cost to the firm if it continues to pollute, in terms of lost employee motivation, lost sales and perceived actions from politicians, would ultimately be taken into account in the firm's calculations and the knock-on effect thereby would be to influence firms to reduce their emissions.

Classical economics have been criticized by institutional economists, for example, who argue from a public choice perspective that a society with actors who make optimizations from a purely economic standpoint cannot take responsibility for the environment (Söderbaum, 1995). Söderbaum, for example, argues for including ideology in theories of public choice to

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[5] Translated, the title of the publication is: Put a price on the environment - Economic arguments in environmental policy. Swedish title: Sätt pris på miljön. samhällsekonomisa argument i miljöpolitiken, SNS, 1968.

[6] My translation from the Swedish original.

account for influences other than the purely monetary on environmental behavior (1973; 1995).

Söderbaum was one of the business administration researchers in Sweden who took an early interest in environmental issues. In his Ph.D. thesis (1973) he developed an analytical model, "position model", aimed at improving decision making and planning. He argued for including all relevant stakeholder situations and goals, not only the economic but also, for example, ecological and health situations and goals. Stakeholder positions (goals or situations) could then be used in analyzing the consequences of different decisions over time and the impact on present and future stakeholder positions. He pointed out the gradual creation of interdependencies between parts in a system and decision-processes and the importance of acknowledging them in decision-making (Söderbaum, 1973:266-67). Söderbaum's suggested position analysis could help decision-makers co-ordinate decisions based on mapping and identifying multiple dimensions of interests, situations, and consequences. The information could then, for example, be used in planning the use of strategic or scarce resources or in analyzing the ecological consequences of, say, building a new road or industrial park.

In addition to Söderbaum, in the early 1970s a few marketing scholars raised concerns about the impact marketing practices had on the ecological environment. They reacted to the materialistic value system inherent in consumer marketing models that failed to incorporate ecological responsibility (Fisk, 1978). Henion (1978) suggested ecological marketing as a strategy to solve the environmental crisis. He argued for a shift of focus from the supply side to the demand side of the economy in directing governmental efforts to protect the environment. According to him governments and business should design programs and develop targeted communication to decrease consumer demand for products that were relatively harmful to the environment and stimulate demand for environmentally compatible products. He reasoned that environmentally conscious consumers could initially account for profitable target markets that would increase with growing ecological awareness spurred by governmental educational efforts.

This view was not fully supported by other marketing scholars. For example Schultz (1977) claimed that if a firm was environmentally responsible it could create positive attitudes towards itself and its products. But she saw the difficulties firms had in communicating environmental issues. She argued therefore that environmental responsibility mainly created goodwill, as opposed to increased sales, due to the firm's inability to convey its record of responsibility in a credible manner through advertising. In addition Helgesen (1978) did not fully support Henion's view, but hypothesized that ecological concern as a purchase determinant may rather be "a question of long-term attitude change through internalization of social values rather than of advertising effects" (1978:318).

In the field of accounting Lydersen (1977) proposed a method that incorporated natural resource accountability into corporate accounting systems in order to integrate environmental costs with other costs of the firm and thereby increase awareness of the value of natural resources. With a few exceptions, environmental costs still have not been integrated into accounting systems. She also argued for a system that would follow the resource from its origin to final point of consumption, a method that was developed in the 1990s and is increasingly in practical use[7]. Other more recent research in the area of "accounting and the environment" seeks to find new methods to quantify and account for investments to improve firms' environmental behavior (Grey et al, 1993; Azzone & Manzini, 1994; Bebbington & Gray, 1993).

Apart from a few previous publications the majority of the environmental research in the field of business administration has emerged since the early 1990s. The intensified public debate and focus on corporate responsibility has spurred research in various fields of business. One of the larger areas of interest has been environmental management. Strategic environmental

[7] Several analytical tools have been developed for this purpose for use in industry. The method is usually referred to as "from cradle to grave" or, more formally, "life cycle analysis".

control and management at the firm level have been the focus of several studies. For example, Bhat (1996) argues that the "green corporation" is the next competitive advantage where firms, instead of resorting to costly pollution control, place a greater emphasis on pollution prevention. He suggests a number of tools the firm can use in its greening process, for example product-design strategies, product-stewardship programs and green communication techniques.

The bulk of strategic management and marketing literature in the environmental field extend the strategic models to include environmental protection management tools. The suggested tools and strategies often have an internal (to the firm) focus. Re-orientation of strategy is often regarded as necessary to avoid the risk of (external) threats like increased environmental compliance costs, lost sales due to consumer shifts to environmentally-apt products, and deteriorated image among buyers, employees and investors (Bhat, 1996, Pettie, 1992).

A few researchers have concentrated on the development of management tools and systems to implement environmental responsibility into the firm (Welford, 1992; 1993; Welford & Gouldson, 1993; Noci, 1995) which go beyond mainstream strategic management. They argue that old management techniques and models will not be sufficient in supporting a development towards more environmentally responsible firms which must be guided by a focus on sustainable development and how to achieve it from the firm's perspective (Hart, 1996; Shrivastava & Hart, 1995). Welford and Jones (1995), for example, argue that we cannot achieve sustainability goals by just relying on developing alternative materials, reducing waste, or using energy more efficiently. But the corporate responsibility must reach deeper in committing to socially and ecologically responsible approaches involving the whole organization. Issues like equity and equality, human rights, futurity and impacts on eco-systems are suggested for integration as well, while they conclude by suggesting a management system for sustainability that involves different stakeholders in planning, implementation and auditing (ibid). This perspective is more far reaching in its scope than the main stream strategic literature. It incorporates both wider social and ethical criteria that go beyond the responsibilities of firms today, placing emphasis on a time-based perspective that goes from the current situation to the futurity (long-termism) (Welford & Jones, 1995:220-21).

There has been steady flow of studies focusing on the single firm or a single industry and their related environmental strategies. Many are empirical studies of environmental strategic change and the forces involved in that change. Halme (1996), for example, studied the Finnish forest industry and its changed environmental strategies. Her study shows a gradual change from regulatory compliance-orientation to sustainable forestry management, a change in orientation largely driven by the demands of the German paper market. Studies of other industries or firms have produced similar findings. Instead of regulatory pressure on its own, it has been more a question of firms reducing polluting practices during the last few years as a result of pressure from consumers, environmental groups or the media (cf. Roome, 1992; Rothenberg et al 1992/93; Schwartz, 1997).

Several studies look at the environmental processes in the firm as a reaction to the environmental movement outside of the firm (cf. Schot, 1992; Shrivastava, 1992) some from a risk/financial impact perspective (Shrivastava, 1994). One stream of research has analyzed the influence on financial markets due to environmental accidents (Piesse, 1992). The conclusions from these studies are that environmental accidents vocalize external pressures to change - by influential stakeholders – and that these are more effective in changing firms' environmental behavior than internal pressures.

Others studies discuss how environmental responsibility can influence investment decisions and calculations (Zaring, 1999). Zaring's study showed that there is a tension between the need to make long-term decisions designed for adaptability and the short-term needs for efficiency in the capital allocations of a firm. Zaring developed a framework to evaluate the use of flexibility principles in investment planning that would integrate the short- and long-term needs. The evaluation of the framework was not fully conclusive. Using data from the oil industry, Zaring showed that the model/principles of flexibility could be used under some restricted situations but uncertainties about future needs, existing vs required skills and knowledge and other contingencies in the firm, would always play a role. He stressed that flexibility could and should be used to make resources used in the firm's operation adaptable to changing environmental demands and thereby influence firms' environmental behavior and priorities.

Another stream of research in the environmental field concerns individual environmental attitudes and behavior. Solér (1997) studied consumer attitudes and their impact on the consumption of "ecologically friendly consumer goods". The research problem in focus was why consumers varied in their buying of environmentally adapted products. Using an imperative method, phenomenography, to help describe consumer conceptions of what it meant to buy ecologically, she argues that the extent to which a consumer buys ecological products is determined by that consumer's perception of the product. The greater the distrust of the firms' ecological claims and the lesser the sense of seeing their buying as being part of nature, the greater the tendency not to buy ecological products. Conversely, the greater the conception of being part of a system, that of nature, and the greater the extent to which the individual's sense of influence or efficacy is tied to that individual's buying behavior, the greater the tendency to buy ecological products.

Thogersen & Bech-Larsen (1993) studied individual recycling behavior and Nelissen & Scheepers (1992) discussed environmental consciousness and what impact it had on behavior. Thogersen' & Bech-Larsen showed that motivation to recycle is only one of the factors influencing behavior. Opportunity and ability were also strongly influential in directing recycling behavior. Societal support systems (opportunity) must therefore be there - or alternatively be communicated that they exist but are not perceived to be there - to support greater motivation to recycle. Similarly, systems more in line with people's knowledge and habits (ability) to perform recycling activity, rather than complex and difficult new systems, were considered better at supporting successful recycling behavior.

Many empirical cases have also supported the rise of classifications of corporations and their environmental behavior and attitudes. For example, Tuininga & Groenewegen (1993) classified firms as reactive, receptive, constructive and proactive, and Hultén & Östlund (1994) looked at firms' strategies for environmental cooperation and classified them as defensive, reactive or active. Their cases showed that all firms in the study had strategies for cooperation with other firms on environmental issues. The firms with the most defensive strategies usually cooperated with their competitors to develop their environmental approach. Reactive firms usually activated their supplier relationships when faced with an environmental problem. The most active were firms who cooperated with their customers in developing environmental strategies. Similarly, in a study of intra-industry behavior, Östlund & Larsson (1994) found evidence of cooperation, rather than competition, between competitors towards finding solutions to ecological problems.

Omrcen (1992) and Roome & Hinnells (1993) have discussed the role of product development in corporate reorientation towards more environmentally adapted behavior. Omrcen's study showed that instead of environmental demands supporting new product innovation and development, firms tended rather to modify existing products on a piece-meal basis. Omrcen also tried to obtain an understanding of the situation of product developers and designers in internal structures of the firm, using network analogies in explaining the possibilities for environmental product development (Omrcen, 1992b). Östlund (1994) also argues for studying networks to understand environmental processes, but at the industrial level rather than the organization level. Since firms commonly develop new products and modify old ones in industrial structures where they are already established, the change processes of an individual firm are best understood in relation to its industrial network. Håkansson & Waluszewski (1995) also use the network approach to understand the introduction of recycled fiber in high quality printing paper. They view the technical development involved in this process as a non-linear, cumulative and interactive process that could only be understood in view of the established roles in the network.

Summary

The foregoing review witnesses the evolution and complexity of ecological problems and researches addressing them, from early "conservation and preservation" approaches from the early 1900s stemming from naturalist insights regarding the inter-relatedness of sub-parts of natural systems and their sustainability, up to the present day.

Social science attention to ecological problems emerged in the 1960s and was heavily influenced by ecological (natural) systems paradigm of the naturalists before them. However, environmental issues were first approached by economists struggling with "costs and benefits" of undesirable polluting behaviors of firms and individuals, focusing on incentives for their governance and change. Admirable for their tenacity of purpose, by the 1980s it became clear that the political, technical and social complexity of "incentivizing" desired behavior was greater than traditional economic assumptions could explain, model or change.

Thus, by the 1980s studies of attitudes, industrial inertia, political economy, organizational change, business strategy, and consumer behavior appeared to try in their various ways to fill-in the gaps left by economic approaches to ecological problems. In short, most of the approaches (with the exception of Dahmén, 1968) could be characterized as focusing on substantive change, be the *substance* of change the change in attitudes, change in cost accounting categories, change in polluting behavior, change in market strategy, etc. This thesis focuses on the restraining or facilitating influences on industrial system change, and as such is more focused on *change processes* than on substantive change.

The majority of the environmental studies mentioned above have developed within already established theoretical disciplines. Some of the studies have contributed to the theoretical development within their field and others have developed new models and theories to further the knowledge of business and the environment. This thesis positions itself within already established disciplines but in the hope of increasing the knowledge of environmental change processes *in industrial systems*. Since our research interest focuses on environmental change in industrial systems and especially the underlying processes that enhance or restrain development towards more environmentally-apt processes and structures, an inter-organizational perspective will be used as well as an institutional approach. With such an approach, we argue that multiple levels of analysis are required in order to integrate understanding of the firm's behavior in contexts that are driven by multiple actors influenced by internal (to a given or focal firm) dynamics but foremost by the context and dynamics prevalent in the network of relationships of which the firm is a part.

PART II THEORETICAL ASPECTS OF INDUSTRIAL CHANGE

Chapter 3: Inter-organizational, technological and institutional change processes: influences of structures and processes on industrial change

As the purpose of this thesis is to describe and understand the change processes in industry in relation to societal goals of ecological sustainability, this chapter aims at reviewing and exploring inter-organizational and institutional literature and possible explanations of industrial organization and change processes.

First an introduction to the chosen perspectives will be given followed by a theoretical discussion on the organization of industrial change. The review of organizational and inter-organizational literature will build an argument for using a network approach to study industrial change. Secondly, an overview of the theoretical foundations, underlying ideas, theoretical concepts, and research focus in the organizational institutional approach will be given. Then we will look into how inter-organizational and institutional literature approaches industrial and organizational change. An attempt to integrate the two theoretical approaches will be made. Particular interest will be paid to forces influencing change processes to find theoretical concepts suitable to analyze industrial change in the context of environmental demands.

Introduction

The bulk of management literature focusing on industry and ecological matters has an intra-organizational or intra-industry perspective. Change towards more ecologically apt solutions involves change of strategies and the development of appropriate tools to implement such strategies. Problematic from an intra-firm perspective is how to structurally design its (internal) resources to achieve the stated environmental goals. In the intra-industry perspective focus is on firms with competing products, for example on car manufacturers working on alternatives to the combustion engine. The possibilities for a firm's strategic change are tied to the relative (power) structure *within* the industry and the costs of changing towards more environmentally suited behaviors. Of interest in these studies are the relative costs of transactions for alternative choices of change (White & Hurst, 1994). The higher the transaction costs for changing the less likelihood of change.

We acknowledge the importance of focusing on individual firms, and we review organizational change literature, but this review and the thesis emphasize that any given firm is both part of a larger system of actors, technology and institutions and is embedded in industrial systems in which organizational strategic action will occur. A single firm is dependent on resources outside its control and therefore must interact with other firms and muster other resources to effectuate changes characterized by the complexity associated with ecological problems. These "other firms" and "other resources" may in fact lie outside of the focal firm's industrial system or chain, and therefore the restraining and facilitating forces for or against change may also lie entirely outside of the firm's "industry." For example the development of electric vehicles requires development of new long-lasting batteries as well as the development of an infrastructure to re-charge them - technological, knowledge, and organizational resources that are not readily available within the existing network of actors in the auto industry. Also, inter-industry institutions of governance and professional organizations, as will be seen in the CFC-case, often play an influential restraining or facilitating role in change. In terms of sustainable design and development of organizations we believe it is important to identify such interdependencies to be able to detect, and possibly alter, a whole chain of polluting behavior. This requires putting as the focus of analysis the design of an industrial system in the context of a specific ecological problem. By doing so we will be more apt to understand restraining and facilitating influences towards changing environmental behavior of firms.

The assuming of an institutional perspective will bring emphasis on forces for change in the knowledge, belief, and rules systems in the study of organizational phenomena. We believe the institutional approach will help put material forces for change, for example technological and organizational resources, in a broader perspective. It will inform us about the forces for change and stabilization that originate from the enlarged environment of which industrial organizations are a part, and how these forces have an impact on industrial processes and outcomes, and, ultimately how that in turn influences society. Attention will be given to conceptualizations of forces for change and patterns of institutionalization that relate to inertia and isomorphism in organizational change.

We will therefore emphasize in this chapter how industrial relationships influence change processes and patterns of structure and change. In particular the literature on industrial networks will be investigated (Johanson & Mattsson, 1992). The chosen approaches allow us to study the dynamic processes generated by properties inherent in existing institutional and industrial systems as well as how they influence change. For example, the development of environmental policies may be considered as an initiator of change processes towards more environmentally suited behavior, but the processes may be shaped and altered by processes pertaining to exchange relationships and resource dependencies in the industrial network.

Organizational change and the organization of change activities in industrial systems: multi-level perspectives on change, its governance and its sources

<u>Change on the organizational level - organization design</u>

Where a single organization is the focal unit of analysis, organizational *change* is a problem of organizational *design*, according to one of the predominant schools of thought on organizational change, strategic management. One definition of organizational design provided by Van de Ven & Joyce (1981), is "the structural arrangement of resources (land, labor, and capital) of an organization in order to achieve desired ends." This definition points to the single organization as a decision- making unit that can control its resources and activities purposefully. Although Van de Ven and Joyce broaden their perspective on organizational design to include environmental constraints, and they define organizational design as the "*processes* by which structural arrangements are created and changed" (ibid p. 3), the bulk of the organizational design literature focuses on strategies to design or re-design the *internal* structure of an organization (c.f. Nadler & Tushman 1988).

In the strategic management school of thought organizational structure usually describes "an organization's basic design or anatomy as well as the management processes used to coordinate and control its operations" (Hrebiniak, Joyce, & Snow, 1989:4). In this view organizational structure (design) can be altered as a result of managerial decision-making (design processes) that could be, but do not necessarily have to be, based on pressures from the environment. This is to say that change results from the implementation and integration of intra-organizationally designed structures and processes governed through internal hierarchies.

One critical problem with this intra-approach relates to how industrial activities are actually organized functionally. Modern industrial activities are performed typically by multiple firms, tied to each other by dependency relationships. The knowledge and resources invested in a production chain are divided among several actors, who individually seldom possess the power to control the whole chain of activities and resources. This problem is reflected in the standardized environmental management tools and systems that have been developed in the 1990s, where the need is specifically addressed for integrating the environmental performance of suppliers.

Industrial change in economic systems

Lifting the unit of analysis from that of the problem of change/design at the firm level to that of economic change problems leads us to fields of economics and economic history. Here the focus is on industrial development and its role in societal economic development. The theory development in this field is largely based on thoughts developed by Veblen (1904) and Schumpeter (1939), who stressed the importance of studying the *process*, i.e., dynamic aspects of economic development. Dahmén (1950), for example, follows Schumpeter in his interest in economic transformation processes: the origins of new products, technology, ways of organizing, markets, and their struggle and victory over old products and production methods. His doctoral thesis presented a critique against the research of economic business cycles where economic aggregates were the basis for the analyses to understand economic development, for example GNP. Dahmén proposed the study of the change process itself to better understand driving forces behind investments, technical-economical considerations, and the development of new products and production methods. According to Dahmén there was a need to study processes on micro- and meso-levels to be able to understand macro phenomena such as change of industrial structure.

According to Dahmén (1950), the transformation process has two components: the introduction of innovations (the positive pressure for change), and the reduction in old combinations of production factors (the negative pressure for change). His analysis focuses on the change of production and the difficulties and opportunities in adapting encountered by the firm due to the different pressures the transformation creates. He also identifies different development- or transformation processes depending on the structural and institutional stimuli or limitations for development. Complimentarities between technological and economic factors and how they have co-developed in earlier stages are significant influences for understanding how large a development potential a certain change will have. In the early stages of development, these complementarities can be out of balance with each other (or be more or less co-developed) which creates "structural tension" between the complementary factors. This tension can in turn start a development of one or several of the complementary factors to create balance. Dahmén refers to these unbalanced complementarities as "development blocks" through which a series of structural tensions between them can lead to balance.

Structural tension can occur when, for example, an environmental regulation is imposed on an industry. Hypothetically, at the time for implementation of the regulation, there might not be any readily available solutions or clear alternatives as to how to solve the problem. This can cause tension in the product and its market, production processes, available technology, or input resources. The time that elapses between the emergence of structural tension and its balancing could be a result of several factors or events. For example, delays in the change process itself stemming from the time required for the destruction of old technologies paralleled with new technological development to replace them, institutional factors, for example legal or structural barriers or opportunities for change, the degree of economic development forces or incentives in the development blocks themselves, or factors resulting from the relative position the actors have in their own networks with regard to their control over necessary resources for effectuating change.

Change in industrial networks

Some researchers in business administration have also lifted the unit of analysis to that of industrial markets and their dynamics when investigating change processes. The industrial network perspective[1] focuses on industrial markets and the behavior of actors in these network-like structures. For this tradition, the "industrial network" is a model that describes an economic system where actors (usually firms) are connected with each other through linkages, or exchange relationships.

Following Alderson's (1957; 1965) work in marketing[2], the network approach focuses on exchanges of heterogeneous demands and supplies in

1 Several schools of network approaches can be identified within organizational theory and sociology. If no other school/approach is mentioned we use the term "network approach or theory" for the industrial network model that has emerged from the research on industrial markets in Sweden and Europe.

2 Wroe Alderson is considered to be one of the most important influences in marketing theory. He applied a systems approach to marketing where he classifies the household, the firm, and the distribution channel into three organized behavioral systems in marketing, where exchanges take place between the systems in order to match demand segments with supply segments. For an extensive review of Alderson's writings, see: Hunt, Muncy, and Ray (1981). Alderson's General Theory of Marketing: A Formalization. The Review of Marketing: The American Marketing Association, pp267-272 (also reprinted in Sheth & Garrett (1986).

the total system of consumers and firms, although the industrial network approach does not include the behavioral system of the household in its model. The network approach views the actors as involved in economic activity that transforms resources to finished goods and services for consumption by end users. The system of links of exchange relationships between actors is used to describe and analyze behavior as well as constituting the structure of the network.

The industrial network approach views the network of actors as embedded in a larger context of social, economic, and technological systems (Håkansson, 1992). Network studies, compared to technological or intra-industry studies, have generally a greater focus on organizational processes and how exchange relationships between actors might restrain, facilitate and/or influence change at the industrial network level.

The main focus in industrial network studies is on connected relationships were there is an element of economic exchange, usually involving buyer-seller relationships. Easton (1992) discusses the integration of non-economic exchanges into network analysis as well. He argues for using "atmospheric" analysis, where both economic and other forms of relationships are covered. The network relationships that are included in this analysis are direct and indirect relationships including economic exchange, and direct relationships not including economic exchange.

Johanson and Mattson (1988; 1991) make a distinction between governance structure, as a network of exchange relationships, and the production system, which are seen as two levels composing the industrial system. In their latter work (1991) they added the institutional setting where the industrial system is embedded. They characterized the institutional setting as an organized web of "ideas, beliefs, values and attitudes ... closely related to cultural political, social, and legal conditions" (1991:267). They argued that a change in institutional setting may be important in that it relates to

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<u>Marketing Theory: Classic and Contemporary Readings</u>. South-Western Publishing Co, Cincinnati, Ohio.).

the change of the actors' "network theories", or perceptions of the industrial network, that in turn will influence strategic adaptations.

The network of exchange relationships involves exchange between actors on the industrial market, where the production system is constituted of resources and activities that are employed, performed, transformed, and combined in production. The exchange relationships act as structures governing the production system through coordination and direction of the resource flows and production activities. Emphasis is put on the interconnected nature of the production system that produces interdependence on the network level, through the organization of the actors. By connecting the production level with the actors and overall governance or organizing principles, the network approach facilitates analysis of micro behavior and macro outcomes.

Håkansson and Johanson (1992) offer a related but slightly differing view of which elements form a network. In their view actors, activities, and resources are all individually related, forming their own network structures, as well as being interwoven in a total network where all three networks are bound together through several forces. Hence, emphasis tends to be more on elements pertaining to the exchanges between individual actors and how they relate to the employed resources and performed activities. An example of a study performed in this tradition is the description and analysis of the processes and technical developments made in the paper industry with the introduction of recycled fiber in printing paper (Håkansson & Waluszewski, 1996). Their study emphasizes the importance of the interactive processes and established role patterns in the network to explain the process and nature of technical change.

In the network approach there are no explicit 'designers' of the industrial system, though individual actors have intentions as well as a certain amount of autonomy and freedom to act. The ability to act depends on the amount of resources the specific organization controls, the relative power, and the specific role or status of the organization in relation to the other actors in the network. Generally the sum of this ability is described as the position of the actor in the network (Henders, 1992).

Instead of organizational design based on internal choice, the network approach outlines design through the governance structures coordinating resources and activities used in the production of goods and services, i.e. in the network of exchange relationships (Johanson & Mattsson 1992). The exchange relationships between actors are voluntary, connected and aimed at controlling resources and carrying out activities in production systems (Mattsson, 1995). Rather than having the internal firm and its resources in focus for strategic change, the network approach defines strategic action by the firm as aimed at "influencing how firms are connected to other firms in networks" (Mattson, 1995:761).

How change processes influence the resulting patterns of behavior in network structures is related to the actors' abilities to adapt and adjust resources and activities relative to each other, and to interdependencies in the economic and technological systems of which they are a part. Influence on the adaptation processes are governed through the exchange relationships, and may result in new ways of organizing resources and activities as well as shaping existing or emergent network structures (Axelsson & Easton, 1992:).

The approach does not, however, make any predictions of the outcome of such change processes. To find indicators of future patterns of network relations or network structure, we can look at the underlying aims for change at the actor level. Actors are supposed to engage in efforts aimed at influencing their position in the network. These efforts are called strategic actions (Johanson & Mattsson, 1991), and could be aimed at influencing actors, activities, and resources, as well as at changing the interdependency structure of the production system.

Technology and Change

The role of *technology* in industrial development and change, as well as that of change toward environmental sustainable development, has also been the focus of several studies. For example, Kemp et al (1998) have described how technical change is locked in to dominant technological regimes that provide barriers to the development of more sustainable technologies. They suggest a strategic (governmental) tool, strategic niche management, to create "protected spaces", or niches, for specific applications of new technologies. The authors argue that government supported niches can act as institutional platforms for interaction between actors from industry, universities, and governmental organizations that will enhance learning of viable technological paths as well as coordinate necessary action to create shifts from less to more environmentally benign technologies.

The importance attributed to technology in solving environmental threats is also evidenced in industry practices and beliefs of industrial actors. In a survey conducted by the Gothenburg Research Institute, the majority of top management in the firms listed on the Swedish Stock Market believed new technological development and innovation would be the primary solution to environmental degradation and sustainable development (GRI, 1993). From this we can trace a widely accepted norm that values technology and the belief in its ability to solve societal problems. We would then expect definitions of problems and their possible solutions to be in accordance with these norms and values. This is especially relevant in our CFC case studies where technological solutions seem to be the dominant "first-round" approach to solving the problems raised by CFC usage. However, the actual solutions developed in our CFC cases vary from technology-focused to technique-focused[3].

Theorists have also characterized technological change and innovation as a primary source of development - economic as well as social. The bulk of the literature on technological change characterizes a sequential "phase" model or process beginning with innovations that spur industrial change activities through transfer and diffusion of technology (Lundgren, 1995). Lundgren studied the development of a new technological innovation, image

[3] We here refer to technique as a method (way of doing) compared to technology that refers to the actual artefact (for example a chemical compound or a machine).

processing, and his study shows strong path dependencies[4] in the emergence of a new technological system. The development of exchange relationships evolved over a sequence of processes - those of genesis, coalescence, and dissemination - which are paralleled by a sequence of decision processes on technological solutions, which are identification, legitimization, and adaptation, respectively.

These sequential, parallel processes influenced the emergence of both the technological system and the new networks of exchange relationships evolving therefrom. Lundgren emphasizes the parallel nature of the processes that create novelty and develop the innovation and its use. According to this view, the role of technology can only be understood in the context of the system that supports and is supported by it.

Research in the field of "sociology of technology" approaches "the causal nature" of technology in economic and social development from the social side. This school of thought advances the position that it is not technology that is the "change agent" but rather technological systems are shaped by social systems in which they are embedded. By studying the interplay between systems of technology, institutions, and their environment, the web of interdependencies between the systems can be demonstrated as well as the societal rationales for developing specific technologies. A technological system is referred to in a broad sense and includes physical objects, production resources, activities and/or processes, as well as to the knowledge that goes into designing, building, assembling and operating objects, activities or processes (cf. Bijker, Hughes & Pinch, 1987/third edit. 1990).

It will be recalled that this broad definition of technology, including activities, tangible and intangible resources, technological components and artifacts, as well as organization, is also represented in the industrial

[4] Path-dependence is referring to phenomena of interrelated, sequential, and historical events that influences future events. Paul David (1985) has used the term extensively to illustrate the importance of including history in analysis of change and directions of change. One interesting study of his is the analysis of the emergence of the QUERTY standard for typewriter keyboards. He shows that several dynamic elements of history, such as a technological lock-ins, learning processes, creation of industrial

network approach. Lundgren, for example, defines technology in a more narrow sense as "clusters of inter-related technologies structured into technological systems" (1991:39), but does not deny the socially constructed element of technology being shaped by, as well as contributing in shaping, societal needs and wants.

According to this stream of literature the processes of change towards a specific technological solution could be explained by the interdependencies in the technological system that will create path dependencies and technological lock-ins. But the process is heavily influenced by entrepreneurial activities influenced and shaped by societal needs and wants. For example, the solutions can involve the creation of interdependencies around a specific technology or material used in a specific product or production process pertaining to a specific knowledge nurtured in the past (Bijker, Hughes & Pinch, 1987/third edit. 1990). In our case study of CFCs we will witness the restraining power of interdependencies between CFCs, production processes, and specific knowledge nurtured in past practice in one instance, and in another instance the facilitating power of "less tightly coupled" interdependencies which encouraged the application of innovation.

Studies of industrial responses to environmental threats often include the role of existing technology in shaping the outcomes of such change. For example, Omrcen (1992) reports on an environmental product development project where participating firms were more easily able to environmentally adapt their products on a piecemeal basis rather than integrate environmental goals into the organization and management of product development, i.e., technological interdependencies, path-dependencies and existing technological norms on "best" solutions influence the organizational response to ecological problems.

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structures, and falling production costs, will positively feed back to reinforce a specific solution that will push the economic system into path-dependency.

Organization and functioning of industrial systems

To better understand *how* technological interdependencies, norms, and path-dependencies influence organizational responses to ecological problems we need a better understanding of the procedural organizing and functioning of the actor networks in which these individual organizations are embedded.

Networks as interdependent open systems

Inter-organizational approaches view organizations as open systems dependent upon their environment for needed resources and legitimacy (Pfeffer & Salancik, 1978). Individual firms seldom possess or control all the needed resources, for example, alternative technology or sufficient knowledge to change or modify a marketing or production system to become less ecologically harmful. In addition to internal resources, firms have to rely on other actors in the industrial system to get access to essential resources. Resources in this approach are usually understood to be "any valued activity, service, or commodity" as originally defined by Cook and referred to by Easton & Araujo (1992:65).

This system of interdependent and connected actors forms the industrial network (Axelsson, 1992). It constitutes a specific structure coordinated through exchange relationships linking actors, activities, and resources in a certain pattern. In its most general sense the industrial network constitutes a structure built on exchange relationships between actors and the employment and transformation of resources in production activities, i.e., the network of exchange relationships between actors and the production system together form the design of the system.

The network approach sees the corporate actor as dependent on external resources that are controlled by other actors. Internal resources and the organization of these are looked upon as essential for the actors' possibilities to develop relations to other actors in the network, and through those relations gain access to necessary external resources. The development of relations is a cumulative process where the position of the corporation in the network and the actors' strategic intentions are seen as critical for the possibilities for development (Mattson, 1987). The focus is on the development of the network, or individual actors within the network, rather than on economic sectors or industries within an economy. For example, one problem that this type of study tackles is how relations between actors are developed or handled over time and how complementary external and internal resources are adjusted in response to changes in capacity regarding a given type of resource. In our CFC cases we will examine how a specific resource interdependence (that of the usage of CFCs) differs in different cases, and we will trace the interaction of these differences with the stability of existing network activities, relations, and structures.

Thus, in the industrial system there exist resource interdependencies that influence individual actor's possibilities to change as well as the pattern of change. The design of the system then is both a result of the structure of the relationships and interdependencies in a more static sense, as well as the processes of exchange activities that continuously take place which might alter or stabilize such a structure.

Accordingly, if one could identify these intentions, processes and structures in a network with regard to environmental problems, there might be possibilities to find factors explaining the evolution of certain network practices and structures in relation to developments towards sustainable environmental practices. For example, if there is a general increased interest in environmental issues within the society as a whole, a single actor may see opportunities in pursuing environmentally beneficial activities to change its position in the network. The actor can try to achieve this through initiating activities aimed at defining environmental problems in the existing network and start the organization of activities and the mobilization of resources to find solutions. This mobilization could be the incorporation of new actors in the network in order to get control of or access to specific resources that offer solutions to the problems.

Characterizing interdependency in industrial networks

To understand strategic, environmental changes in dynamic industrial contexts we also need to acknowledge the interdependencies between the forces of stability and change in the systems under study. These forces will emerge in technologies and technological systems, in the structures of the inter-organizational network, and in the institutionalized norms and rules in the network. One way to depict the processes of implementing ecologically sustainable strategies in industrial systems is to use concepts and ideas from loose coupling theory, founded in the disciplines of social psychology, social interaction theory and organization theory. The presence of loose and tight couplings provides a background for understanding persistence *and* transformation in organizational networks, as well as the prerequisites for strategic action. With many loose couplings there might be a need to tighten up a few strategically important relationships to enhance the process.

For example, empirical evidence indicates that in order to handle change in inter-organizational networks, actors need to handle various contradictions and tensions that emerge when the network undergoes a structural transition. Studies of the introduction of new recycling systems have shown how new structures of relationships between actors in the industrial network emerge when new, recycled input resources are introduced in a distribution system (e.g., Håkansson & Waluszewski 1996). The introduction of the new technology was possible due to the stability of the relationships between the actors and earlier investments made. But the new technology also put pressures on the existing structure and new relational structures developed. Interdependencies between existing and new actors could be characterized in terms of the "strength of couplings" between them and such an understanding could lead to better anticipation of the likely consequences of strategic action.

Loosely Coupled Systems

Implicit in different types of industrial network analyses is often the notion that networks are defined as strong bonds or connections and relationships (cf. Andersson, 1992) among actors. The term network is frequently associated with words like link, connection and interdependence. The existence of stable long-term relationships between buyers and sellers of manufactured products was one of the important empirical observations which first guided the early work of the Industrial Network Approach (e.g., Hammarkvist, Håkansson & Mattsson, 1982; Hägg & Johanson, 1982; Axelsson & Easton, 1992). Industrial networks were observed to be stable but not static. Stability was a characteristic used to describe the circumstances under which change processes in networks were enacted. Descriptions of bonds of different types implied that actors were tied to each other in different ways.

But industrial network researchers have also pointed to the existence of weak, potential and residual relationships in networks (Araujo & Easton, 1988). In addition, descriptions of the mechanisms by which actors in networks, through *indirect* connections, influenced other actors have further strengthened the notion that industrial networks are multidimensional systems of both tightly and loosely coupled bonds among entities.

The concept of *loosely coupled systems* has appeared in a number of organizational studies. The phrase "loose coupling" appeared in the literature in the 70s, e.g., in Glassman (1973), but it was in Weick's (1976) article on educational organizations as loosely coupled systems that theorization of the concept was initiated. A large number of researches and articles have since been written about loose coupling.[5] Weick defines loose coupling as a situation in which elements are responsive, but retain evidence of separateness and identity. In a later article, Weick argues that loose coupling is evident when elements (e.g. individuals, sub-units, institutions) affect each other "suddenly (rather than continuously),

[5] For a review and reconceptualization. see Orton, J.D.&Weick, K.E., "Loosely Coupled Systems: A Reconceptualization", *Academy of Management Review*, Vol. 15, No. 2, (pp. 203-223), 1990. At the same time as Weick's article was published four other organizational perspectives were published: transaction cost economics (Williamson 1975), institutional theory (Meyer&Rowan 1977), population ecology theory (Hannan&Freeman 1977), and resource dependence theory (Pfeffer&Salancik 1978), see list of references. As Orton&Weick note, each of these four perspectives has a more distinctive paradigm, a more compact theory, and more empirical support than is true of loose coupling. Without comparison, the first of the five paradigms, i.e. transaction cost economics has attracted most

occasionally (rather than constantly), negligibly (rather than significantly), indirectly (rather than directly), and eventually (rather than immediately)" (Weick, 1982). Weick conveys the image that coupled events or elements are responsive, but that each element/event also preserves its own identity and some evidence of its physical or logical separateness. A basic problem that the concept attempts to capture and explain is the simultaneous existence of rationality and indeterminacy, e.g., in and between organizations. As Thompson (1967) noted organizations appear to be both determinate, closed systems searching for certainty and indeterminate, open systems expecting uncertainty.

Change in loosely vs. tightly coupled systems

The use of the loose coupling concept depends on the level of analysis. When studying change processes, the term directs attention to what happens between loosely coupled elements in systems, but the change efforts are basically affected by the pattern of tight coupling within and loose coupling between elements in the system. These patterns of coupling change over time and the open system approach also makes boundaries amorphous, although this can vary depending on what aspects of the system are under consideration. There is always a certain amount of arbitrariness involved in the decision as to where to draw the boundaries that separate units. Attention is thus partly shifted from structures to processes. Put in an industrial network context, the idea of loose and tight coupling can help describe, analyze and develop models of large global distribution systems, for example, where tight coupling "within" systems and loose coupling "between" systems do not necessarily coincide with boundaries shown in theoretical models of industrial systems.

The framework and ideas of loose coupling draw attention to the nature of change in organizational systems, for example pointing to important dynamic aspects like the trade-off between *adaptation* to exploit present opportunities and *adaptability* to exploit future opportunities. This is often described in the context of *stability* and *flexibility*. A network

interest among distribution and marketing researchers.

conceptualization and loose coupling theory consider openly the mutual dependence between the dynamic constructs above. *Flexibility* in industrial networks is required to modify current activities so that certain actors can indeed adapt to non-transient change in the network. Network actors must be able to detect changes and retain a sufficient pool of novel responses to accommodate these changes. But total flexibility can be dangerous as it makes it impossible to retain a sense of identity and continuity (Weick, 1979). *Stability,* (e.g., in industrial networks) also provides an economical means to handle new contingencies. Weick argues that as with total flexibility, a total adherence to past practices and past wisdom in an organizational system can be as disruptive as total flexibility because more economical ways of responding would never be discovered and new environmental features would seldom be noticed.

Theoretical assumptions and ideas underlying loose coupling can serve as a vehicle to develop new knowledge on the dynamics of organizational change in industrial settings. Loose couplings, combined with viewing organizational systems as networks of interconnected relationships, can generate new intriguing questions. A discussion of the functions and dysfunctions of various degrees of tightness in organizations/networks can be used to generate suggestions for approaching the dynamics of industrial networks. For example, Andersson (1996) applied the ideas of loose and tight couplings in a longitudinal study of a firm's strategic change. He found several important implications for a firm's ability to act or strategically change depending on the trade-off and interdependencies in loosely and tightly coupled networks. He also found that the patterns of loose and tight couplings will change over time, hence influencing the structure of the network along with the individual exchange relationships.

Another study shows similar results. In her study on the internationalization of the transport business, Hertz shows that industrial relationships can go through varying forms of life cycles (Hertz, 1993). Thus, a relationship between two firms can be established, move into closer cooperation, be enlarged, cooperation can become looser, and perhaps be dissolved. The successive re-organization and adaptations made in the relationship can radically change the interactions and exchange contents and thus the general characteristics of the relationship.

In this situation of changing patterns of loose and tight couplings in the network and constantly emerging changes in the individual relationships, single actors have intentions to stabilize and to change the present order of things in the network. The implementation of new environmental strategies can be part of these intentions. In the network approach the single actor's strategic change intentions are referred to as changing the firm's strategic position in the industrial network. The strategic position will be determined by the actions of the company and by the actions of the other actors in the network. A position change can be defined as: a change in relationships with other actors in the network; a change in the identity of counterparts; a change in strengths of relationships; or as a change in the role(s) of an actor and/or in the importance of the actor in relation to other actors (cf. Johanson & Mattsson, 1992; Henders, 1992). Each firm's opportunities to alter its position in the network can be assumed to depend on the emerging patterns of loose and tight couplings in the inter-organizational network (Andersson, 1992). The ability to organize such change is partly tied to the actor's position and control over resources. Actors with the power to organize change are normally also adaptive and prepared to act on changes in loosely coupled parts of networks in order to cope with the influence of innovative change processes.

We will see in our CFC cases how one actor attempted to use the CFC ban to change its strategic network position. In this case, the actors quickly eliminated lower profit products from their offerings in order to put pressure on its relatively larger and more dominant customers to adopt CFC-free products that were more profitable for the supplier. They attempted in other words to capture more resources in the network using the CFC regulations to enhance their power/bargaining position.

There are several important strategic questions in regard to change in networks. One concerns integration. Tightly coupled entities can experience a loss of flexibility and adaptability when structural changes occur while the identification of organizational structures that allow for short- *and* long-term structural change may be important. For single actors there are also questions concerning the balance between local adaptation (tightly coupled by adaptation to specific actor/s) and overall standardization of activities. This can be conceptualized as a trade-off between loose and tight coupling. Synergy may be reached by connecting the activities of local sub-systems. However, these same connections can have disadvantageous effects and can also hinder the development of more advantageous connections between other configurations of actors in the networks. Thus, identification and activation of direct and indirect relationships, through tight and loose couplings, will be of importance in designing inter-organizational network structures which can best retain innovation and novel solutions, e.g., to environmental problems.

An important question relating to change in networks is how partial autonomy and self-determination through loose couplings can be created within a context where the actors are embedded in dynamic networks of both strongly and weakly connected relationships. The network approach suggests that mutual interests connect industrial actors. This mutuality gives a certain self-determination in relation to each other and towards other, non-related actors, but also restricts each actor's degree of autonomy. The dynamic aspects of this paradox constitute an important managerial issue for the actors in the network. How actors perceive and resolve this paradox is influenced by the "institutions" also acting in and on the network, as we will describe next.

Institutional theories and change

The studies of change in industrial networks discussed above emphasize the role of stability for change but focus on the properties embedded in network exchange relationships (cf. Johanson & Mattsson, 1991; Håkansson, 1992; Lundgren, 1991; Hertz, 1993; Anderson, 1994; Andersson, 1996). In addressing large societal issues, as with ecological problems, there is a need for an understanding not only of the stabilizing forces in the industrial system itself, but also of how the industrial logic relates to broader meaning structures represented, for example, in professions, nation states and cultures.

The organizational institutional approach focuses on the impact of the institutional environment and processes on industrial actors' activities and organizational structure. This approach informs us of the forces for change and stabilization that originate from the enlarged environment of which an organization is a part, and how these forces have an impact on the form and direction of the industrial process for change.

Theoretical foundations and focus in organizational institutional theory

The institutional approach, within contemporary sociological thinking (new institutionalism), focuses on the impact of the institutional[6] environment and processes on organizational activities and structures. One underlying idea is that the organizational structure and operations are reflections of and are shaped by the rules and patterns in the wider system of which the organization is a part (Scott & Meyer, 1994; Scott & Christensen, 1995). Although institutional studies comprise great variety with regard to phenomenon, actors (individuals, organizations, networks, organizational fields), methods, and analytical approaches, common themes are connected to questions of how institutional arrangements shape, mediate, and channel social choice (DiMaggio & Powell, 1991).

The new institutional school of thought in organizational sociology emerged in reaction to early organizational research where the organization was theoretical and taken at face value. The organization was considered as being a sovereign entity with clear boundaries and autonomous decision-making, having its own goals, technology and resources. Empirical studies had shown inconsistencies and practical predictive problems with regard to organizational realities and the theories of rational actors, technical contingencies, and strategic choice. These phenomena were described in an

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6 Not all theorists are prepared to give a singular definition of institutions but Scott (Scott & Christensen, 1995:xiii) has proposed that "institutions consist of cognitive, normative, and regulative structures and activities that provide stability and meaning to social behavior. Institutions are transported by various carriers - cultures, structures, and routines - and they operate at multiple levels of jurisdiction"

influential article in 1972 by Cohen, March & Olsen. Examples of their findings and those of other organizational researchers were: the existence of de-coupling and/or loose coupling between organizational structures and performance[7]; the observation that strategic decisions and policies in organizations were established but seldom implemented; no apparent relational or sequential connections between problems, a tendency of prioritizing "solutions" over "problems" in choice situations and decision-making in organizations; the observation that organizational activities were often based on routines, procedures and other institutionalized rules rather than on rational calculations (March & Olsen, 1989).

As a result of the new institutionalists' mounting criticism, dominant organizational perspectives changed to emphasize organizations as structured and depicted by their environment[8] rather than merely adapting to internal technical requirements (Scott, 1992; 1987a). The new institutionalists came to emphasize organizations as ..."connected to and .. constructed by wider social environments" (Meyer & Scott, 1992:1) where the importance of institutional cultural patterns and norms was accentuated.

The interest in the influence of informal and formal rules and patterns has several theoretical roots. Many of the institutionalists mention Weber's work on institutions as a primary source of influence. Weber took an interest in both the nature and dynamics of social relations, organizations, and institutions as well as in analytical aspects of various societal spheres. One part of his work, which directly ties in to the interests of the new institutionalists, has to do with routine aspects of social relations. He developed concepts for the major orientations of social action, affective and traditional (routine), and their crystallization into different types of uniformity, customs, and conventions (Weber, 1968).

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7 For a discussion of the concept of coupling see earlier in this chapter.

8 The term environment is commonly used in organizational literature to clarify or communicate organizational boundaries or what is outside an organization's decision domain, but the term is used in a very broad and general way. Although used and conceptualized in many ways, there is now an agreement of the importance of analyzing organizational environments. For a deeper discussion on different conceptualizations of environment in organizational research see Scott, 1987or Perrow, 1986.

The theoretical roots of the institutional approach also grew from structural-functional sociology. The main arguments were that functions determine organizational structure, and that organizations and their structure can be understood by analyzing their functions[9]. The works of Parsons and Selznick were the most influential on the interconnections between economic, political and societal arenas and have been instrumental in providing important research questions to the new institutionalists.

Parsons, for example, took an interest in patterns that shaped action in social systems. He saw social systems as "essentially a network of interactive relationships" (Parsons, 1951:51) where social action occurred and also created stability to change patterns. In his later work he theorized the governance of the western industrial economy and stated that "the new industrial economy was neither purely rationally individualistic... nor collectivistic... [but] was governed... by... normative structure, legitimized in terms of values grounded in cultural bases (Parsons, 1977:57). Many of the new institutionalists in organization theory also emphasize the role of cultural values in shaping change and influencing structural forms or organization as will be seen below.

One of the early influential institutional writings on the dynamics of organizational life was by Selznick. He took an interest in the adaptation patterns organizations made over time as a response to pressures from the environment and the influence it had on changing organizational structure - institutionalization. He conceptualized institutionalization as a process of organic growth, wherein organizations adapt to strivings of internal groups and the values of the external society. In his work, institutionalization refers to *the adaptive process by which an organization conforms or shapes its structure and defends its own institutional values in reaction to strivings of internal groups and presence of societal values* (1957)[10]. Thus, Selznick saw

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[9] For a more thorough discussion on the institutional approach, see Charles Perrow's review and critique of the Institutional School in Complex Organizations, Random House, New York, 1986.
[10] Among the earliest and best known writing on the structural-functional school and its application to organizations was done by Philip Selznick. The most important writings are: An Approach to a Theory of Bureaucracy, American Sociological Review 8 1943: 47-54; Foundations

organizational change as a 'socialization' or 'legitimization' process, where the organization becomes accepted by and incorporated into larger society.

Another influence came from the work of Herbert Simon who, with others, took an interest in the conditions under which actors could be considered rational. He criticized the early theories on the "economic man" as being over simplified in its assumptions concerning actors driven by self interest optimizing decisions based on full information on all available alternatives. Instead he proposed the administrative man, still motivated by self interest but, with limited knowledge and access to information on alternatives and who would make decisions by satisfying "reasonable" criteria[11], i.e., he argued that choice under uncertainty was path dependent driven by psychology not by resources. Later, he and March developed the concept *bounded rationality* to depict the constraints - or givens - that influenced individual decision-making in organizations. They argued that individual choices are made in environments with goals, sub-goals, expectations, routinized activities and programs, etc. which are the basis for or parameters of the framework in which decisions are made in organizations (March & Simon, 1958).

Contemporary institutional theory & organization theory

Since these early writings on institutional theory, concepts have evolved and undergone changes from relatively descriptive to fairly defined constructs susceptible to empirical tests. But the main ideas on overall institutional patterns influencing organizational structure and change and that change is driven by a process of institutionalization still remain of interest to the new institutionalists. In addition, most of the new institutionalists share basic assumptions on organizations as a part of and dependent upon their environment/context, which have implications for the study of organizational behavior and structure. Similar to the network scholars, institutionalists emphasize the embedded nature of organizations. The unit of analysis is usually whole organizations, organizational or

of a Theory of Organizations, American Sociological Review 13 1948:25-35; and Leadership in Administration, New York: Harper & Row, 1957.

11 Simon's theoretical work as described in Scott (1987a).

professional fields, or a system/sector, like education, and the studies are holistic, evolutionary, comparative, and process oriented.

Contemporary institutional studies focus on the structure and activities of modern society. Some authors refer to institutional as "a rule-like, social fact quality of an organized pattern of action...and....(their) embedding in formal structures, such as formal aspects of organizations, that are not tied to particular actors or situations..." (Zucker, 1987:444). That is, institutional behavior is an organized, enduring pattern of action and relations if:

1. the pattern becomes embedded in formal organizational structure (e.g., centralized vs decentralized decision-making, divisions of labor and authority along departmental lines);
2. action and relations become embedded in organizational structure due to objective or independent influences or demands present in an organization's environment, (e.g., regulations, economic realities, resource dependencies).

Such demands or influences may exert pressure on the organization as a whole (such as regulations), or they may exert pressure on individuals or interest groups within an organization (such as labor unions) who in turn seek to make the organization responsive.

One way of illustrating differences within the organizational approaches that view organizations as embedded in wider contexts is to question if the primary research focus is on general phenomenon (phenomenology) or on practical/pragmatic (realist) issues and if the issues are micro or macro in orientation - see figure 3:1 below.

	Phenomenology	Realist
Macro	Institutional culture	Resource dependence, Population ecology
Micro	Organizational culture	Actor oriented

Figure 3:1: Organizational embeddedness: Organizational schools[12]

Institutional analysts study institutional phenomena at both macro and micro levels of society as well as linking the levels. Micro studies often look at single, competing actors/systems (organizations, nation states, communities etc.), while macro studies often look at larger entities with multiple actors, like society, world system, networks or organizational fields.

Phenomenologists assume organizations to be socially constructed and they emphasize meaning systems as carriers of institutions. A basic assumption of the micro phenomenologist is that actors create the world of meaning while the macro analysts assume a constructed meaning in a system of a highly rationalized culture (Meyer & Scott, 1992). The organized world (many organizations that carry out specialized functions and tasks) in modern society and the structure of the organization creates meaning on macro level.

Basic ideas of macro phenomenologists are that actors are embedded in a rationalized culture and are organized based on historical events that are

[12] The classification is inspired by John Meyer who gave a doctoral seminar on institutional theory at Stockholm School of Economics in 1994.

independent from organizational ideas (or strategies) and bear imprints from the rationalized environment. The organization is a creation of its culture.

Realists emphasize the importance of the organizational environment in their studies in terms of looking at organizations or organizational populations' structural adaptations to resource dependencies. Population ecology is an example of the realist school where whole organizational populations (an industry or group of organizations competing for the same resources) are studied and structurally understood in terms of adaptations to existing resource pools. Changes in the resource base will change the birth and death structure of the population. A more general macro realist approach is the resource dependence approach. An overriding assumption is that structure/policy in organizations are driven by forces in a wider competitive environment. The actor is embedded in the enlarged environment (for example a network) and change in structure occurs as a result of changes in the resource base. Another branch of realists study individual organizations or actors and their adaptive strategies to the environment - and often to a highly visible problem such as customers' changed demand towards environmentally sound products.

Thus, the four approaches in organizational theory depicted in figure 1 emphasize different aspects of the organizational environment as well as the predominant level of analysis for each approach. Realists focus on structural and behavioral issues relating to actors, individual organizations or organizational fields, and resources connected to them, while phenomenologists emphasize issues such as the influence of culture, symbols and meaning on organizational life. Our study could be classified as being Realist with both Macro and Micro orientation. Our study is primarily a network study, but will integrate institutional elements such as the norm and meaning systems prevalent in the network. The network consists of actors with interconnected technologies that are governed by industrial exchange relationships but the actors are also embedded in larger systems of institutional rules as well as meaning systems that will influence their ability and capability to change.

Substantive issues in institutional studies are for example: the evolution of industrial sectors; the nature of organizational fields or industrial sectors; patterns of impact of organizational culture or rituals/policies; and the influence of change processes on structure. Theoretical explanations focus on linkages between the environment and the actor. The nature of the actor is often depicted in terms of its identity, structure and/or activities/routines and how it is represented and influenced by the social, cultural and technological systems in the organizational environment.

Institutional theorists argue that stability and survival of specific organization of industrial activities is largely a result of the external legitimization of the resulting organizational forms. Legitimization is achieved through conforming to laws, formal rules, and other direct legal or economic control systems, as well as by adapting to broad social and cultural meaning systems (Scott & Meyer, 1994; Powell & DiMaggio, 1991).

The process of organizational patterning and conforming to the environment is called institutionalization, or, as defined by Meyer, Boli, and Thomas (1994:10): "The process by which a given set of units and a pattern of activities come to be normatively and cognitively held in place, and practically taken for granted as lawful". Thus, institutionalized rules and patterns have an impact on the form and direction of the industrial process for change.

The institutional approach focuses on the influences these institutional processes exert on emergent and enduring organizational forms or structures. Organizations that experience pressures to change will develop ties to their relevant environment through mechanisms of isomorphic change in order to reduce uncertainty as to which solutions to adopt. Isomorphism has its roots in biological science where it refers to a similarity in appearance or structure of organisms belonging to different species or races. Isomorphism in biology is an evolutionary process whereby non-optimal forms of a unit in a population become extinct as optimal (most efficient) forms survive (i.e., natural selection). Competition for resources results in isomorphic form since it encourages a limited/optimal/"fittest" form.

Social scientists have borrowed the term competitive isomorphism in organizational population ecology theory which suggests that the environment selects the optimal form of organization, and that non-optimal forms of organization do not adapt but merely die. Institutional Theory is opposed to such a literal application of isomorphism. IT posits that non-optimal organizations may adapt to their environment and thus enhance their chance of survival. Additionally, there is no assumption that surviving organizational forms are at all the most efficient. Surviving organizational forms, for IT theorists, merely adapt to Institutional environments which exist *de facto* as social artifacts which are not necessarily bound by natural laws or principles which demand optimal (i.e., most efficient) forms. Therefore, IT rejects *competitive* isomorphism in favor of *institutional* isomorphism.

To sum up the above discussion: through isomorphic mechanisms for change, organizations facing the same environment will tend to adopt the same organizational solution. For example, an environmental regulation regarding the specific use of a resource will exert isomorphic pressures on organizations targeted by the regulation to adopt conforming practices or structures that solve the environmental problem. The solution (action) could be, for example: a different technology used in the production of a product; organization of research and development activities to find alternative solutions to the problems faced by the organization or set of organizations; organization of activities aimed at collecting information about environmental problems areas that could be subject to future legal action; or organization of lobbying activities aimed at influencing future environmental policy activities or formulations of environmental standards.

We will see in our CFC cases that there are indeed institutional factors working on the emergence of solutions to the CFC problems, and that these institutional factors vary by case and thus their influence is different. These institutional factors influence the processes of framing, searching for and legitimizing of possible solutions/actions to solve the CFC problems. But it is not only an "institutional" explanation that suffices to clarify our cases. To prepare for a richer analysis for understanding both the substance of the changes as well as the processes leading to them, we are helped by integrating institutional theory with the network approach.

Understanding the substance of change and change processes in and of industrial systems

Next we integrate the network approach to understanding exchange in industrial systems with the institutional approach to understanding organizational change. We review the importance of relationships in industrial change and the role of institutional processes in such change. The section which follows this section provides an integrated theoretical background for understanding both stability *and* change in industrial systems.

The importance of relationships in industrial development and change

Studies of change in the industrial network approach have been a predominant theme during the last decade[13]. Either explicitly through studies of change and change processes (for example Andersson, 1996; Anderson, 1994; Hertz, 1993; and Lundgren, 1991), or implicitly by studying a marketing phenomenon where change has been an integral part of the phenomenon as such (for example Henders, 1992). These studies and similar research indicate that change in industrial systems is complex, multi-faceted, and tied to interdependent relationships inherent in the system, influencing both structures as well as change processes. Restraining and facilitating forces pertaining to network properties and relations as well as technological and other social factors influence the direction and magnitude of the changes.

[13] For an excellent review of perspectives on change see Andersson, 1996:16-48.

Producing products or services demands resources external to the firm. In order to gain access to external resources, industrial actors build exchange relationships. Internal (to the firm) resources and their organization is seen as critical for the firm's ability to develop relations with other firms that provide access to external resources. Exchange relationships thus constitute the web of the industrial network. The development of relations is a cumulative process, where the company's position in the network will influence future developments.

A firm's ability to change is dependent upon its network position and upon its strategic intentions in the network, as well as upon other firms' positions in the network and their strategic intentions. The intentions and the positions of the actors in the network hinder or facilitate change and development of its actors and the network itself (Henders, 1992).

In addition to the influences of network position and the strategic intentions of actors on their ability to change, the network approach identifies other dynamic factors influencing change including: the actors' ability to change due to their relative power in a network, their ability to control, mobilize, and coordinate resources (Axelsson & Easton, 1992); the availability, complementarity, and versatility of resources in and outside of the network; and finally, the organization, coordination and routinization of activities of the network and its actors (Håkansson & Snehota, 1995).

These elements of industrial network change constitute a basis for an analysis of the industrial change processes resulting from pressures on environmental adaptation. A number of structural and behavioral forces related to the firm and its network that will exert influence on change process can be identified. For example, available resources, links to other firms, institutions and interest groups, the firm's position in the network, and finally the ability to mobilize external resources and stimulate new activities are examined in our CFC case studies of this thesis. We will show that when an environmental regulation is imposed it is an important analytical question as to whether direct and indirect exchange relationships of a given actor offer enough capacity, complementarity, force and resources to adjust or change in accordance to the conditions imposed by the new regulation. In one case we will see how changes or development of one resource controlled by certain actors (CFCs, for example) may be restricted or interrelated to changes in other resources controlled by other actors in the network.

Changes or restrictions in one part of the network could also act as a driving force for changes or constraints in other parts, both in terms of behavior and as a result of the actors' relative positions in the network. That is, the opportunities and restrictions within a given network's structures may define whether forces or barriers for industrial change exist.

In summary, the industrial network approach identifies the major forces for change within *existing* networks, and analyses of network changes usually focus on the organization and coordination of actors, resources, and activities to handle these changes. Complementing this perspective with an institutional theoretical perspective helps understand some of the boundaries within which actors in a network cognitively and socially frame both resource problems and routine/non-routine activities, as well as the influence of such framing on "acceptable" solution search, design, development, and change results.

<u>The role of institutional processes in industrial change</u>

A major research area within the institutional school is the study of (design) processes by which change in organizational structure comes about and is sustained over time. As mentioned earlier in this chapter it is argued that pressures from outside and/or inside the organization shape the structure of the organization through a process of institutionalization. Organizations are influenced by pressure from social forces in their environment. Examples of such pressures are laws, regulations, and societal norms, as well as the influence of internal groups or professionals who share goals and ways of working stemming from socialization processes which occur external to the organization (schools and trade organizations for example). Responding consistently to these pressures is considered to be a "process of institutionalization" by institutionalists. This behavior can in turn lead to isomorphism (in form, behavior, and/or structure) with the institutional environment, which will likely increase the probability of survival of the organization or sets of organizations.

In contemporary institutional theory the institutionalization process is treated as a variable, and its cause is separated from its major consequence which is "[the] establishment of relative permanence [of patterns of action and relations] of a distinctly social sort" (Zucker, 1987:444)[14]. The end-product (or dependent variable) is an emergent and enduring organizational form or structure. The independent variables are the external and internal pressures shaping and sustaining organizational form/structure. The intervening variable is the process (i.e., institutionalization) by which the organization becomes institutionalized (i.e., establishes enduring patterns of action and relations) to a specific structure.

In institutional theory, organizations are seen to "interact with elements in their institutional environment whenever decisions must be made about issues concerning both the organization and the community of which it is a part" (Hirsch, 1975:327). Under some conditions environmental and internal pressures lead organizations to be guided by legitimized elements present in the society which in turn may lead to *institutional isomorphism* (I-iso). Institutional isomorphism refers to a constraining process that forces one unit in a population to resemble other units that face the same set of environmental conditions. Hence, for institutional theorists I-iso is a process of homogenization of organizational form in a given organizational field (cf DiMaggio & Powell, 1983; Zucker, 1987).

Thus, institutional theory suggests that organizational change is a response to external and/or internal pressures, and by adopting a certain form or by changing its activities accordingly, the organization can enhance its chance for survival or growth. Institutional theory posits that since organizations sharing the same field are subject to similar pressures, then similar organizational forms/structures should emerge within that field. But by

[14]Hughes as cited in Zucker, 1987. The parenthetical insertions are offered by the present author for clarification and appear nowhere in Hughes' work.

what mechanisms do environmental/internal pressures bring about institutional isomorphism (i.e., the homogenization of organizational forms/structures) within a field?

In an influential article, DiMaggio & Powell have conceptualized and suggested an empirical definition of "institutionally defined organizational fields" (1983:148). By organizational field they mean "organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products" (ibid p.148). A field is empirically defined by measures of connectedness and structural equivalence[15] among organizations and their members. Connectedness is defined as the "existence of transactions tying organizations to one another" (DiMaggio & Powell, 1983:148) and includes both formal contractual ties as well as informal organizational ties like personnel flows. Structural equivalence refers to "similarity of position in a network structure" (ibid) where similar organizations have the same ties, of the same kind to the same set of other organizations.

Clearly the concept of organizational field is very similar to the concept of "industrial network" in the network approach, though the latter takes the ties, or relationships between actors as the primary unit of analysis or the mechanism used to identify and put boundaries to the study. In institutional studies, the relationship is seldom the primary unit of analysis. In fact there need not be any direct links between the actors at all in a field, other than indirect links to the same resource base (as in, for example, DiMaggio, Powell and Zucker's studies) or to the same symbolic or cultural system (for example, Myer and Rowan).

Not all organizational fields are necessarily institutions. Organizational fields evolve into stable, mature patterns of interaction and relations among organizations and their members. As fields mature, members become accustomed to "ways of doing business," structuring relations/transactions,

[15] DiMaggio (1986), among others, has used a block modelling approach to identify an organizational field.

dealing with the state. Institutional patterns/relations take on "taken-for-granted" assumptions and beliefs about "the way things are done." (Scott, 1987b). An organizational field becomes defined as an institution through a process of *structuration*.[16] In institutional theory, four elements comprise the structuration process; 1) an increase in interaction among organizations in a field; 2) the emergence of defined inter-organizational structures of domination and patterns of coalition; 3) an increasing information load with which organizations within a field must contend; 4) the development of mutual awareness among participants...(of organizations in a shared field)...that they share a common enterprise. (DiMaggio & Powell, 1983:148).

In summary, the basis of an institutional theory view on change is that: 1) organizations are influenced by their institutional environment; 2) internal *and* external pressures can facilitate isomorphic change among organizations within a given field; 3) such pressures result from a structuration process that evolves among interacting organizations and members in a given field; and 4) increasing structuration of an organizational field will lead to isomorphism among organizations within that field.

Institutional theory is less contingent than the network approach making predictions about understanding organizational change and change at the organizational field or network level. Whereas the network approach offers insight as to *where* to look for understanding *what* changes are occurring, if they are occurring in networks, institutional theory suggests some substantive changes that can be expected under certain circumstances.

Integrating institutional theory with the network approach can lead to making propositions about change like the following:

1. The greater the increase of *activities* between *actors* focused around legitimate *resources and exchanges* resulting from change pressures,

[16] The term 'structuration' refers to the dynamic process whereby structures come into being and are reproduced through time by interaction among actors (cf Giddens 1976 and 1984). Institutionalism focuses on structuation as a more collective construct, while the industrial network approach attempts deliberately to incorporate actor intentions (as Giddens attempts as well).

the greater the isomorphic structuration of organizations and the field/network will be.

2. The greater the degree of structuration of a field or network at the time of introducing pressures for a given change (e.g., new regulations on polluting behavior) the greater the likelihood of isomorphic responses to the pressure for change, and conversely the lesser the degree of structuration at the time of introducing pressures for change; the greater the likelihood of pluri-morphic[17] responses to change pressures.

We will examine this reasoning in our CFC cases, which interestingly enough vary along dimensions of connectedness, activity intensity, resource co-ordination, technological path-dependencies, etc. Understanding this variation and the change processes that emerged from the CFC ban (a pressure in the institutional environment) is essentially attempting to come to grips with understanding stability and change in industrial systems.

Stability and change in industrial systems

Stability, change and inertia in organizational fields

In the institutional approach cultural aspects and biases of behavior are brought forward as the underlying rationale influencing patterns of behavioral change. Actors, or organizations, act or respond according to highly invisible and embedded conventions that might be outside the boundaries of the network. DiMaggio (1993) argues for including attributes and observable cognitions in the study of network change in order to be able to observe the potential influence of culture on constraining and shaping behavior in networks. The restrictions that are embedded in the existing relational and positional structures and also the decision rules and tactics that are used by actors in the process of change are of particular interest in

[17] "Pluri" from the Latin "pluris" a combining form meaning several or many (Websters', 1980). The term pluri-morphic is not used in the organizational literature but is developed in this thesis to take into account cases of non-isomorphic responses.

identifying when actors operate under uncertainty and to analyze their influence in shaping the outcome of such change.

In institutional studies of stability and change, the concept of inertia in organizations and organizational fields is used to explain various constraints acting upon actors and organizations (cf. DiMaggio & Powell 1991; Gresov, Haveman & Oliva 1993). Inertia is a term borrowed from physical sciences (i.e., physics) and has been applied in social sciences by way of metaphor, applying the idea of inertia to describe/explain that organizational behavior has communicative power (like most rich metaphors). However useful it may be, the concept of inertia as applied in the study of social systems and social change requires greater specificity if it is to help us find the explanation we seek.

Inertia in physics relates to the first of three laws of motion formulated by the seventeenth century scientist Sir Isaac Newton. Newton's first law, the Law of Inertia, states: "An object at rest remains at rest, or if in motion remains in motion in a straight line and at the same speed, unless acted upon by an unbalanced force" (Newton as cited in Brinckerhoff, Cross & Lazarus, 1959:703). In addition to this definition Webster's (1980) offers a few more simplified definitions of inertia: a tendency to remain in a fixed condition without change; a disinclination to move or act. In physics the tendency to continue whatever motion the object possesses is a result of the body's mass[18].

Put simply, inertia is a law describing a state of any physical body in motion or at rest. The law consists of direction and speed components. If speed is zero (and thus direction is irrelevant), the body's inertial state is at rest. Achieving a change in speed and/or direction is to change the body's inertial state.[19]

[18] Mass is defined as "the property of an object by which it resists changes in its speed or direction of motion. Inertia and the pull of gravity on an object (that is its weight) are both results of an object's mass" (Brinckerhoff, Cross & Lazarus, 1959:703).

[19] The experience of inertia is easily recognized in the physical world. Imagine sitting on a bus. ..."At the moment the bus starts to move, you remain at rest with respect to the ground. ... Hence *you* seem to move toward the back of the bus but only because the bus has started to drive out from under you. Once the bus is moving at a steady speed you, too, travel at the same speed. ....In other words you are traveling at the same direction and ... speed as the bus. But as soon as the bus changes either the rate or ... direction of its

The use of the inertia metaphor in social theory is both explicit and implicit. Its implicit use is more frequent than its explicit use. Used imprecisely it loses specificity and therefore explanatory promise. Even explicit use does not guarantee explanatory value if such explicitness is also imprecise.

DiMaggio & Powell (1991) explicitly but imprecisely invoke the inertia metaphor in reviewing sociological institutional theory. For DiMaggio and Powell, institutional inertia provides "constraints on organizational rationality" -- the theoretical sources of which are described differently in old versus new schools of institutionalism (pps. 12-14). They suggest that the "sources of inertia," in old schools of institutionalism are *vested interests.* In new schools these sources are *legitimacy imperatives.*

Inertia in physics is a state relative to motion or rest. Inertia "constrains" a change in state (i.e., motion, direction or speed).

Scott's (1992) study of school reform processes offers an example of implicit use of the inertia metaphor when he suggests that "forces are mobilized calling for reform" (p. 116). It is not peculiar to Scott to characterize social action as "force" or "movement." In an insightful effort to better specify inertia in social systems, Gresov, Haveman & Oliva (1993:184) specified it as being equal to "the inverse of the instantaneous rate of change." Thus, by way of metaphor, social change is defined in relation to social inertia.

This specification of social inertia can only relate a metaphorical idea of "moving bodies" (or systems) by definition. For if inertia is defined as the inverse of the instantaneous rate of change, and the "body/system" is at rest, the instantaneous rate of change equals 0 and inertia is undefined (1 over 0 is an undefined quantity). Additionally, and equally important, if the "body/system" is in metaphorical motion then the natural tendency to continue in a given direction exists "unless affected by some outside force" according to such imprecise applications of the inertia metaphor. Why focus on this imprecision? Because the metaphor has a tendency not to

motion, you immediately become aware of that change. If the bus [turns] to the left, you *seem* to move to the right - because you maintain the same direction you had before. If the bus slows..., you feel yourself traveling toward the front of the bus - because you tend to keep the same speed you had before." (Brinckerhoff, Cross & Lazarus, 1959:126).

function in some relatively common instances of change without more precise specification.

For example, just how institutional "social inertia" acts as a source of "constraints on rationality" and how such constraints on rationality are related to organizational change is not explicitly clear -- unless one equates organizational change with rational and resistance to it as irrational. Explicitly it loses explanatory power via an imprecise use of the inertia metaphor.

Another example is that in physical bodies, a change in inertial state simply cannot result from internal changes, whereas in social systems change can come from within, endogenously, in addition to changes initiated from the outside, exogenously.

Yet another example is that of "small social" systems. What of a small firm that "fails to change and keep pace with the times"? That is, one that fails to change with market /institutional dynamics? Instances of small firms driven by "a strong proprietor" who is less responsive to market dynamics and subsequently fails are not uncommon. And conversely, the ability of many "larger systems" or firms to change/adapt to the same market/environmental pressures is also relatively common. But the application of the inertia metaphor as applied by Scott and others to social systems would assume that larger firms (which have greater "mass") would require larger forces for change than smaller firms, and indeed, smaller firms would always change before larger ones in response to the same pressures.

We suggest the combining institutional theory with the industrial network approach can better specify social inertia and thus lead to making more robust propositions about social change. The use of the inertia is purely metaphorical and should not be confused with the strict laws of physics, but we still think it could be illustrative using the concepts from physics as a simile.

For example we equate:

a) degree of structuration and loose/tight coupling of social systems to that of "density of mass" in physics, and secondly

b) degree of path-dependency to that of direction and "internal force" (like that of the driving wheels of a vehicle) to that of velocity in physics, and thirdly

c) the general process of increasing or decreasing structuration/coupling and path-dependency in a social system to that of motion (or rest) in physics.

These further specifications could then lead to consistent rather than inconsistent explanations of small and large social system behavior. For example, if our small firm is tightly coupled and the degree of structuration in its local network is high (small but dense "social mass") and its path-dependencies (technological and knowledge) are also relatively high (driving force in a given direction), then it is consistent with physical inertia laws to suggest that this small firm will require considerable force to change.

We wish to point out, that underlying frequent characterizations of "social inertia" is a physical metaphor in which social entities are characterized as bodies in motion. Precision in understanding social change (i.e., theoretical precision) benefits from being explicit and clear about the assumptions implicit in the metaphors used in explanation.

For bodies in motion momentum is a force resulting from the product of the mass of the body times its velocity[20] (Mm=Mass x Velocity). For example, if two vehicles, a large bus and a small car, travel side by side at a constant speed on a straight road they will have the same velocity. But if they keep the same speed when rounding a corner (encounter a similar pressure for change), it requires greater force to change the direction of the bus due to its greater mass and therefore greater momentum to continue in a forward direction compared to the smaller vehicle. The greater the momentum the more difficult to change direction (inertial state), for

[20] Velocity is "the time rate at which distance is being traversed in a particular direction" (ibid:709).

moving objects which is translated metaphorically and imprecisely to "social movement."

We must be more explicit if we are to incorporate resistance to change as part of our metaphorical reasoning. We propose to do so. For the concept of inertia, if better specified, holds promise as a powerful explanatory and communicative device in understanding change in social systems.

In the analysis of CFC cases we use the inertia metaphor and further attempt to specify social properties and their relations/influence on stability (remaining at rest or resisting change in "motion") versus change and its direction. To accomplish this, we must also review some additional concepts of social institutional theory relating to processes that impact the informational search and processing activities of actors in organizational fields.

Isomorphic processes in industrial systems

The institutional spheres of an organization act as arenas where rules or norms are created, "……meaningful action occurs, power relations are formed and concrete forms of social organization are set in place" (Fligstein, 1991:312) that constrain and shape actors' behavior. The actors are embedded in a network of dependency relationships with other actors that will affect the material resources and social relations any given actor has to its relevant environment. Where there a set of rules exists, established and tightly structured relationships, and a clear division of labor, fundamental change is less likely to occur. The ability to set rules or start a change process is a result of power positions within a network. Such positions can be held by a single actor as well as by sets of organizations. Inertia is the result of stable interests of central or powerful actors in the network to maintain at hand some distribution of power and resources in the industrial system. The state may play an important role in maintaining stability or instigating change in an organizational field by, for example, defining the rules for environmental conduct.

Recall that the institutional as well as the network approaches in organizational studies examine restraining processes in organizational action. The institutionalization is the process that constrains the perceived options for organizational change. Through a particular change process, the structure and behavior of organizations becomes institutionalized through pressures toward isomorphic responses, solutions, and organizational structural adaptations. The constraining process of isomorphism is one "... that forces one unit in a population to resemble other units that face the same set of environmental conditions." (DiMaggio & Powell, 1983:149). Isomorphic indicators as described by DiMaggio and Powell are decreases in variation and diversity of forms of organization. Such resemblance is evident in organizational form but can also be observed in organizational behavior.

Thus, for DiMaggio & Powell, institutionalization is defined as isomorphic change. Isomorphic change is a process that constrains the perceived options open to organizations for organizational change[21] in a given field.[22] Structuration is the process by which options become constrained (as perceived by organizational members). In their view organizations must take into account other organizations since they each compete not only for resources and customers, but for political power and institutional legitimacy. They identify three mechanisms of isomorphic change: 1) Mimetic/imitative; 2) Coercive; and 3) Normative.

Mimetic/imitative isomorphism refers to organizations adopting (perceived) successful elements (e.g., structures, responses, technologies, etc.) utilized by others when uncertainty exists about the outcome of an activity or a behavior. Organizations mimic, or imitate, other similar organizations that they perceive to be more legitimate or successful. The similarity can make it easier for firms to transact with other organizations. Especially in uncertain situations, such as poorly understood technologies, uncertainty of the relationship between the means, the ends, and the ambiguity of organizational goals. The greater the uncertainty the more likely organizations are to model themselves on other organizations that are

[21] Change refers to change in organizational structure, culture, and goals, programs, or mission.

perceived to be successful. Imitation can be expected to be prevalent in industrial networks since "... actors are aware that particular actors' changes also create changes for the others. Therefore, the actors watch each other closely ..." (Håkansson & Johanson, 1988). Thus, mimetic behavior tends to create homogeneity in organizational solutions to specific problems.

Coercive pressures stem from the legal, political, cultural, and organizational environments on which an organization is dependent. Such pressures can be felt as force, as persuasion, or as invitations to join in collaboration. Organizational structures and activities in a certain organizational field become increasingly similar as they reflect the rules institutionalized and legitimized by and within that field. As nation-states expand their domain, for example, organizational structure increasingly reflects the rules institutionalized and legitimized by and within the state. The theory predicts that the greater the dependence of one organization on another, the greater are the similarities in their organizational structure, climate, and behavioral focus. It also predicts that the greater the degree of centralization of resource supply for a given organization, the greater will be the pressures on that organization to adopt forms/structures similar to the organization upon which it depends.

The third and last source of isomorphic organizational change is Normative. According to DiMaggio & Powell (1983), normative pressures primarily stem from professionalization of occupations. The major normative influences come from the legitimacy and homogeneity that formal education brings about, and from professional networks that span and influence organizational decision-making. Institutions like universities are important centers for the development of organizational norms among professional managers. Professional education often brings with it a socialization process that instills common expectations (i.e., norms) regarding personal behavior, values, and group interactions and interests. Additionally, educational and professional institutions also develop shared

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[22] "The theory...addresses not the psychological states of actors but the structural determinants of the range of choices that actors perceive as rational or prudent." DeMaggio & Powell, *op.cit.*, footnote, page 149.

approaches to problem framing and solving for their "members" by standardizing decision-making models and tools. Powell & DiMaggio (1991) hypothesized that the greater the reliance on academic credentials in choosing personnel and the greater the participation of managers in professional associations, the more likely it is that an organization will be or become like other organizations in the field.

DiMaggio & Powell (1983) also identify field-level predictors of the extent of isomorphism evident in a particular field. The result of institutional isomorphic change is an homogenization of organizational form. Therefore, the indicators of isomorphism are a decrease in variation and diversity of forms of organization. The variation and diversity variables that describe the organizational field are: similar resource dependencies among organizations; similarity in number and type of transactions with agencies of the state; number of visible alternative organizational models; the degree of structuration; the degree of uncertainty of technologies or goals; and, the degree of professionalization in a field.

Therefore, extrapolating institutional isomorphic change theory to our focal domain, industrial networks facing environmentalism, we could expect that such networks may be highly susceptible to isomorphism, given the lack of understanding of environmental impacts and their handling, as well as the uncertainty involved in pursuing, sometimes conflicting short- and long-term organizational goals. The organizational impact on the environment has just begun to be seriously observed and few organizations have the competence and motivation to understand and handle pressures to change towards ecologically adapted practices. Thus, there tends to be great uncertainty regarding what solutions to adopt when faced with environmental problems. Firms may be motivated to merely wait and see until market pressures and/or legislation force them to either begin to cooperate toward more apt solutions or imitate those firms that do.

Even though individual firms do not directly participate in development towards sustainable practices, those who imitate environmental solutions in industrial networks still indirectly contribute to the environmental compliance. Their imitation could contribute to legitimizing one solution instead of attempting to develop better solutions that are relative. Thus, isomorphic pressures could influence the whole industrial network to adopt a homogeneous solution both through firms that cooperate to develop environmental solutions and through following imitators. In this way, environmental compliance could follow patterns of institutionalization throughout the network.

<u>Stability, inertia and change in industrial networks</u>

The development of exchange relationships, routines and activities will over time create stability in the network structure. A basic assumption in the industrial network approach is that stability is both a restriction to and a prerequisite of change. The process of developing relationships takes time and adjustments, which creates natural adherence in established routines. Changes occur within established relationships through adaptation and problem-solving processes. The property or tendency of a system to remain stable and to resist change has been called inertia as discussed above. Institutionalized exchange relationships will either constrain or facilitate changes in response to changes in the environment.

In the organizational design literature there is general agreement that resistance to change is inherent in the organizational structure. Existing internal organizational arrangements such as goals, authority structure, core technology, and marketing strategy, create and maintain stability as well as influence the direction of change (Hannan & Freeman, 1989). Internal factors are believed to inhibit rather than stimulate change, while forces promoting change are usually attributed to external pressures such as evolving technologies and governmental regulations. As for the direction of change (the organizational response) it is argued to be influenced by the relation between perceived level of external pressures and organizational design that "filter" the response in different directions and to varying degrees. Thus, change is then viewed as a competitive response with respect to competitive pressures.

In addition to internal design, organizational theorists also bring up other factors potentially contributing to inertia. For example, existing investments, structural complexity and interdependence in organizations' internal activity systems, organizational size and age, standardization of tasks and activities, and prior success of change activities, are mentioned. Also, organizational goals have been found to be quite stable over time. March and Simon attributed the sources of goal stability to be sunk cost and assets in capital and know-how, as well as the routinization of organizational activities time (Simon 1976; March & Simon, 1958). The majority of the organizational literature use inertia to describe or explain unsuccessful attempts to change organizational design (usually formal structural arrangements and management systems) in a specific organization. This approach has emphasized the connection between structural elements of the organization and its impact on organizational performance, suggesting a framework for managerial action.

Network studies have displayed interdependencies and inertia in the technological as well as the relational (social) systems. Change and inertia are co-existent and integral parts of network structures and processes. Stability in some dimensions is regarded as a prerequisite to change while change is sometimes necessary to preserve stability in other dimensions (Gadde & Håkansson, 1992). It is argued that we need to understand not only the forces for change but also the forces restricting change. Change and stability are created by actors with different perceptions of how a potential change might influence their activities and their position in the network, while they may react differently to pressures to change. But the majority of network researchers do not study perceptions but mainly actions of the actors and change in their resources. For example, as described by Hertz (1992): change in the network ..."develops mainly through mobilization and coordination of activities and resources".

Empirical studies of technological change have revealed that developments take place through interaction within established relationships; that innovation results from the process of problem definition and search for solutions in local settings; and finally that technological change is evolutionary with accumulation of technical knowledge over time (Lundgren, 1991).

Radical change is rare but small changes and adjustments, incremental innovation, continuously take place in ongoing processes in industrial relations. Actors build relationships over time with integration and standardization of their technological systems that will create technological lock-ins and path-dependent processes. Products, production systems, and administrative routines are coordinated and adapted to each other that will create stability and restrict possible paths of change for the individual firms in the network.

Social relationships between firms partly built on trust and loyalty, is another source of stability in the industrial system. Krackhardt (1992) argues that trust in strong long-lasting relationships is a major resource required to bring about major change in social networks. The existence of a network structure ... "is in many ways a serious limitation of the space of action of the firm" (Håkansson & Johanson, 1988:375). Also, the incentives to coordinate activities and resources to manage change might differ within the industrial network.

Inertia or adherence to network positions and routines is often the result of stable interests of central or powerful actors in the network. With the existence of strong relational bonds, highly interdependent technological systems, and actors with an interest in maintaining the status quo in terms of power positions and activity patterns, inertia will put serious limits to the willingness and ability to engage in re-design of the system. Thus, studies of industrial networks suggest that stability exists in exchange relationships between organizations, i.e., in the network structure, in the technological system, and finally in the pattern of change, i.e., process stability.

The industrial network approach sees the network of actors, resources, and activities as embedded in a larger context of social, economic, and technological systems. However, explicit studies of behavioral response patterns of change that are reflected in society at large or outside the direct exchange relationships of the industrial actors are less frequently seen. For example, some of those behavioral aspects of change have a bearing on the cultural contexts of organizations. In the network literature these are sometimes referred to as the network "logic", "rules", or "norms", but are seldom highlighted or regarded as problematic. The key emphasis is on understanding the actors' activities and possession of resources within the framework of their exchange relationships without any values attached to the behavioral patterns that could be observed.

Thus, how change processes influence the resulting patterns of behavior in network structures is related to the actors' abilities to adapt and adjust resources and activities relative to each other, and to other ties to the economic and technological systems of which they are a part. Influence on the adaptation processes is governed through exchange relationships, and may result in new ways of organizing resources and activities as well as shaping existing or emergent network structures.

Change and structuration in industrial networks

In order to understand change, the network approach emphasizes the importance of a dynamic perspective where industrial change is described as an on-going development process involving several interdependent actors, activities and resources. Interdependencies occur as a result of delimitations of the industrial system where a set of actors and resources are identified. When strong interdependent relationships exist between a set of actors, there is usually a need for coordination between them. The coordination between individual actors therefore influences the coordination of the system through network processes (Easton, 1992). The coordination processes are of a continuing character, where actors, activities, and resources constantly change, modify, enter, or exit the network.

Håkansson (1992) distinguishes two basic, though interdependent, network processes: 1) combining resources and activities, and 2) of actors trying to control the activities and resources. He identifies two main ways of combining resources and activities -- structuring and heterogenizing. If the change process is characterized by elaboration of *existing* ways of combining activities and resources, we have a structuration process. Structuration usually takes place within existing relationships as a result of problem solving interaction processes between individual actors. If the tendency is to find *new* ways of combining activities and resources, it is a process of heterogenizing. Heterogenizing can take place through regeneration within established relations and/or through reorientation or mobilizing of new relationships outside, but linked to, the network in focus. For the network as a whole, the effects of the change processes can vary from revolutionary to marginal, though the former is very uncommon due to inertia and other stabilizing factors of the industrial relational system.

Håkansson likewise identifies two tendencies in the process of struggling for control. If there is a tendency towards concentration of control by fewer and fewer actors, we have hierarchisation. On the other hand if the control over a resource or activity is diminishing, we have extrication. In a change process it is likely that investments to increase control over one resource also means a divestment of some other resources. The processes of hierarchisation and extrication imply changes of relationships in terms of the organization of resources and activities. Thus, there are effects on both the network and on the production system level.

On an aggregate level we can identify patterns of change in a network structure as being of two types; exit and entry patterns (Gadde & Mattsson, 1987). Over time it is possible to identify changes in a specific network structure by analyzing the additions and exclusions of relationships that constitute the network. By analyzing the individual patterns of exits and entrances and connecting them to the actors' changed positions in the network, we can detect structural changes on the network level. Changes on the production system level can be effectuated by identifying changes in the type and number of resources employed as well as the activities performed in the system.

Network processes of change may be the result of one actor's internal motive for change as well as stimulus to change from outside the network. The types of change processes that are typically dealt with in network analysis are those resulting from pressures or impulses for change within interdependencies of the actors and the interconnectedness on the production level in explaining many aspects of change dynamics in industrial systems, institutionalism places these in an even broader dynamic process of the structuration of norm and meaning systems in an explicit attempt to link *outcomes* to constraining *processes.* Both network and institutionalism ultimately acknowledge that to fully understand change, and perhaps predict it, one must look at the "actor" (i.e. strategic intentions in network approaches). New institutionalism does so, not by making assumptions about "the actor" (i.e., rationality vs irrationality) but rather by looking for clues as to how actors' problem choice sets might be influenced by institutional pressures and processes of structuration impacting both what is valued (legitimized) regarding acceptable outcomes, and the accepted means for achieving them (norms). This helps us further specify the "intentions" of strategic actions that the network approach suggests as key components to understanding change processes at the actor level.

Both approaches also employ the concept of "movement" of social systems, and the metaphor of inertia to explain dynamics of change in relation to stability in social systems. In this section our attempt has been to review and integrate the literature related to the network and institutional approaches, in particular with respect to change. We have indicated where we suggest that propositions can be derived from these theoretical approaches, and have set the stage for the analyses of our empirical CFC cases.

Chapter 4: Understanding industrial environmental change

This chapter will narrow our theoretical discussion from the previous chapter by presenting the framework used to analyze our CFC-case. The framework brings into focus the theoretical concepts and variables used to analyze change processes and their outcomes in the ban on CFCs. We close the chapter with a description of how the study was organized.

Analytical framework

This thesis broadly sets out to describe and understand industrial change processes resulting from societal demands to protect the natural environment. Focus is achieved by specifically addressing processes at the inter-organizational and institutional level within the industrial setting which restrain and/or promote change towards sustainable practices. In this section we present our framework of theoretical constructs and variables used in the analysis of the case of banning CFCs. The framework has its origins in inter-organizational and institutional theory, and focuses on restraining and facilitating processes and structures influencing organizational change.

Domain of the study

Obviously in our study factors influencing change in particular directions are bound in time and space. Our analysis of the cases are limited in time to the years between the ratification of the Montreal Protocol in 1987 and the Swedish phase-out in 1995, though earlier organizational, technological, and institutional history relating to the case will be touched upon. Also, the outcomes of change issue needs to be commented on. The outcomes of the CFC change processes in our analysis are by no means static and/or final. Rather, they are to be seen as temporary structures that feed back to existing institutions, technologies and organizations that will restructure and influence future change in the industrial network, technologies, and institutions, and so on.

The study is primarily performed in the Swedish institutional and industrial context though both the Swedish CFC-regulations and industrial networks are internationally connected which will therefore be referred to where relevant.

The domain of this study is illustrated in figure 4:1 below. Our point of departure is 1) a growing societal recognition for environmental management and protection, 2) that industrial actors and other institutions play important roles in facilitating and restraining change towards sustainable practices, and 3) environmentally sustainable practices influence societal recognition for environmental management and protection. Social structural elements and change processes influencing progress toward achieving environmental goals are of particular interest in the study. The specific context is the change instigated by the discovery of the degrading effect the release of CFCs has on the ozone layer.

We view the domain of the study as a problem area identified, defined and constructed by actors in a socially structured, embedded, but not overly socialized (Granovetter, 1985) context. This context is represented by the shaded area in figure 4:1 below. The context provides the media by which structures, intentions, and processes interact through time and space in ways that influence (structurate) problem definitions, outcomes, and their evaluations. The contextual media is comprised of normative influences upon interpretations of problems, desired outcomes (intentions) and feedback from results of previous actions taken and normative evaluations of them. It must be stated that 'outcomes' are defined by temporal and spatial boundaries set by the problem domain and its definition. The actors, institutions, and problems making-up the domain of the study continue, of course, to exist, be re-defined, changed, etc. in an end-less process. Similarly, existing relationships. A common classification of changes is that they are continuous, referring to co-ordination of activities within an existing network, and dis-continuous, referring to changes only loosely connected to the network under study (Lundgren, 1992).

The industrial network approach does not directly deal with regulations or other changes or pressures for change that occur outside exchange relationships in a specific network. We could simplify by likening the network approach to understanding change to that of focusing on changes that begin to affect relationships in a network. Thus, regulations or other external stimuli for change are elements that will tend to be incorporated by the network approach once the process for change has started for individual actors or whole sets of actors in a network. The forces that actually initiate and shape the change are not dealt with to a great extent. The network approach does not explicitly exclude non-economic relationships with, for example, political decision-makers or environmental groups that are outside the *commercial* network, but the legal or institutional environment is implicitly treated as part of the context and therefore only indirectly influences the change process in the industrial network (c.f. Håkansson, 1982; Hägg & Johanson, 1985; Johanson & Mattson, 1985).

Theoretical summary

Both the network and institutional approaches suggest that there exist restraining and facilitating influences on organizational change. These influences originate from both structural as well as dynamic aspects of the industrial system, and come from internal and external sources. The governance structure and patterns of institutional change that evolve during the course of change have their own influence on, and interact in, shaping both the process of change and its outcomes.

Organizational institutionalism goes a bit further than the network approach in making predictions about the interaction of change process dynamics with governance structures which we find particularly relevant to our focal domain. As where the network approach focuses on the outcomes are defined more by the delimitations of the study than as objective results or finality of industrial adaptations to environmental problems.

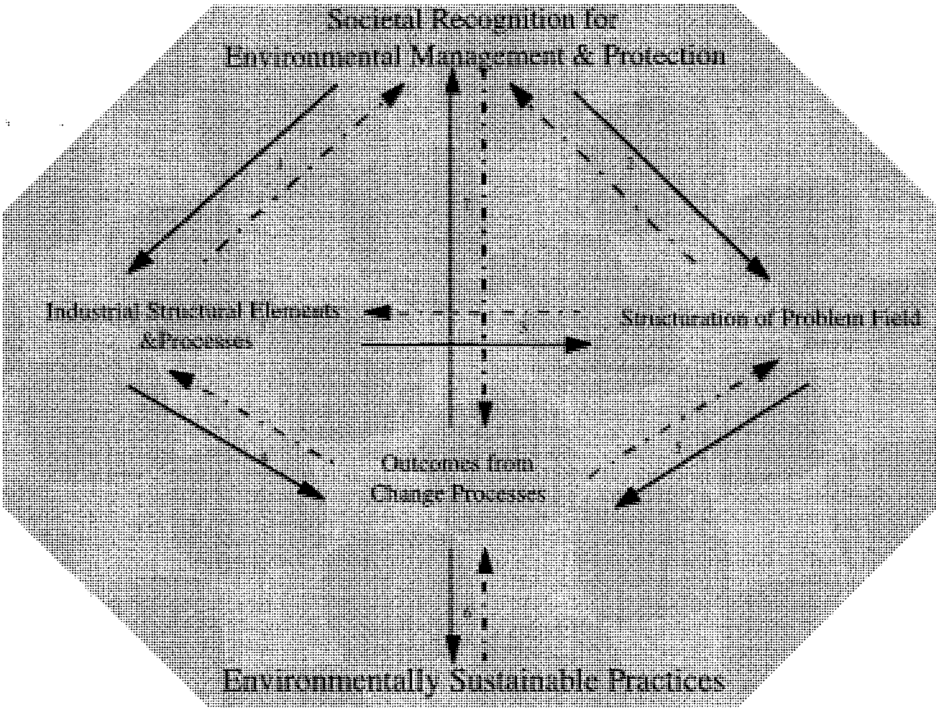

Figure 4:1 Domain of the study

<u>Recognition, structure and structuration</u>

In this study, the recognition of environmental management and protection influence are influenced by both industrial structural elements and processes (industrial system) and the structuration of problem field (institutional processes) represented by arrows 1 & 2 in Figure 4:1. Note that solid arrows represent intentional actions and interpretations at a given time, and that dashed arrows represent the reproduction of structures through time as influenced by on-going structural and institutional processes that in their turn are influenced by the outcomes of earlier intentional actions. These are what Giddens (1984) refers to as reproductive circuits.[1] In our case the recognition of environmental management and protection is (re)enacted, (re)defined, (re)interpreted and thus reproduced over time in interaction with existing and changing structures, as these are influenced by current intentions and normative evaluations of outcomes of actions taken earlier.

The context within which the problem of CFC usage is raised is part of a general recognition for management and protection of the environment. In addition to the influence from an awareness of environmental protection in society, industrial change towards improved environmental products and production processes is also influenced by structural elements and practices pertaining to a given industry and its history. By such elements and practices we mean the technology that pertains to its production system and processes, the institutional setting, and the relationships between actors and their history (arrows 1 in Figure 4.1). This thesis attempts to describe the explanatory value of these industrial elements and practices in regard to understanding change *processes* themselves and ultimately change towards environmentally sustainable practices in industrial networks (arrows 4 + 6 in Figure 4:1).

<u>Environmentally sustainable industrial practices.</u>

We use environmentally sustainable practices not as a precise or measurable tool, but in a socially defined way. Changing towards sustainable development has evolved as one of government's greater challenges (www.regeringen.se, 1999) and will therefore influence society at large - including industry. Since the Brundtland Commission defined sustainable

[1] Reproductive circuits refers to the influence of systems of interaction upon the ordering of social relationships which tend to orient actors toward sustaining (reproducing) those same systems of interaction over time.

development in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, p.43), governmental, NGOs[2], industrial, and other actors have initiated projects, participated in conferences, and developed organizations and institutions around sustainable development. For example, the governmental sector in Sweden has since the UN Conference in Rio in 1992 worked on numerous local and national projects on sustainability. During 1997-1998 the former Swedish Environmental Minister Anna Lindh chaired a governmental commission on "ecological sustainability". Their work developed into today's organization where change towards sustainable development is a natural part in all areas of responsibility of the Swedish Government. Sustainable Sweden has set three goals: 1) the environmental goal - to reduce the impact on the natural environment to what it naturally can process; 2) the resource goal - to preserve the production capacity of our natural resource base and use a larger share of renewable resources; 3) the usage goal - to considerably increase efficiency and effectiveness in the use of materials and energy. These three goals were augmented when the Swedish Parliament decided to support 15 national environmental goals on clean air, living lakes and wetlands, limited impact on the climatic conditions, poison-free environment, etc., that a large number of local, regional and national public organizations are involved in, to further develop and specify. The target is to achieve the 15 goals on environmental sustainability within one generation.

For our purposes sustainable environmental change will be used as a crude indicator in regard to the *direction and guidance of change.* Can we find articulated environmental considerations in industrial change processes or not? If so, how do these influence the processes and outcomes of the change? Can we say anything about the chosen path in terms of

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2 Non Governmental Organizations

contribution to improved environmental impact? For example, is a particular change guided by strategies to improve environmental performance of a particular firm or network of firms? Is the outcome of the change in accordance with goals of environmental sustainability or environmental improvements? Are other solutions available that are possibly better from an environmental impact standpoint? Examples of environmental considerations are evaluations of environmental impact in choice of materials and technologies, integration of environmental standards into practice, strategies of pollution prevention, or environmental management systems in production, product, purchasing and marketing systems, implementation and/or use of environmental performance information in guiding a change process.

The analysis of sustainable industrial change is not intended for cross comparisons of environmental performance of specific industries or networks but merely a tool to understand what role environmental considerations play among other facilitating and restraining forces for change in industrial networks.

Framing and solving environmental problems in industry

The structuration of the problem field (e.g., the 'iso/pluri-morphism' of the problem definitions, solutions and outcomes) influences and is influenced by two key contextual factors: 1) existing industrial structural elements and processes, (e.g., institutional, technological and inter-organizational relationships and history) that either enhance existing structures and relations or put strains on them (arrows 3 in Figure 4:1). 2) Intentions and interpretations of the 'recognition of environmental management and protection' in the general social context (arrows 2 in Figure 4:1).

Interlocking technological systems influence and are influenced by problem definitions (arrows 3 in Figure 4.1) and outcomes (arrows 4 in Figure 4.1) by virtue of 1) organizational, production, and competence/knowledge resources already existing in the actors' contexts, as well as 2) the relative discontinuity required to implement new technological solutions. For example, the early emergence and commitment by a powerful actor to avoid particular technological solutions that are disruptive to the actor's own technological systems may greatly influence the process of problem definition and steer normative discussions away from other (feasible) alternative solutions.

At an inter-organizational level of analysis, established relationships between actors, based on complementary knowledge, similar perceptions, needs, and wants, will work to frame a given problem, develop paths to solve it, and evaluate its outcomes. At an industry level, change towards environmentally sustainable industry is also influenced by formal and informal institutional elements, such as regulations, environmental standards, and societal norms, as well as by institutional processes (arrows 5, 6 + 7 in Figure 4:1) in the industry that take place during the events of change. For example, the organization and coordination of activities by industry associations in the development of industrial environmental standards may be highly influential in problem-framing (arrows 3 in Figure 4:1), problem solution identification (arrows 5 in Figure 4.1) and outcome evaluations (arrows 4 + 6 in Figure 4.1). Also, new technological or social solutions may influence the way we think about environmental problems - or may enhance the detection or recognition of an environmental problem (arrows 7 in the figure).

Although industrial patterns of change can be detected that will conform to the patterns outlined in figure 4:1, it is not a causal diagram. Rather it is intended to be used as a framework to visualize the most important theoretical concepts in this thesis and part of the interactive dynamic that could be prevalent in environmental change processes.

Processes and elements of change in firms, networks and institutions - levels of analysis

Our cases examine the influences the above mentioned structural elements and change processes have on the patterns and outcomes of environmental change in industry at multiple levels of analysis. The levels are: 1) industrial relational network, 2) product and productions systems and, 3) institutional system. As suggested by Mattsson (1997), by adapting a not overly socialized, but socially embedded perspective on change, we are better able to focus on the links between the micro- meso- and macro-levels of analysis. That is, we believe in embeddedness at the micro-level (e.g. the individual dyad) and the meso-level (e.g., the focal net). However we reframe our perspective of these levels somewhat from that of Mattsson. Our framework considers the micro-level to be the individual firm, the meso-level to be inter-firm relations, and the macro-level to be institutional. The elements at each level that we examine in our cases are presented in Figure 4:2, though the analyses are not formally organized around these elements.

Macro Institutional Level

Industry history (age, traditions, norms, etc.)

Governmental Actions/Rules/Regulations

Industrial Organizations/Professional Associations (and their involvement in change)

Meso Inter-firm (focal industrial net) Level

Supplier/buyer relations

Co-operative alliances

Technological path dependencies between firms

Micro Individual-firm Level

Participation in problem defining/solving activity

Adoption of solutions

Figure 4:2 Conceptual Levels of Analysis

Adopting a multi-level approach to the study domain (Figure 4:1), sets the framework for examining how industrial structural elements (mainly macro and meso-level variables) influence the "structuring" of problem identification and definition, which influence commitment toward patterns of solutions, which guide the change processes and ultimately become defined as outcomes in the study.

Our case analyses examine the interaction of structural elements and processes and the forces leading toward homogeneity or heterogeneity of problem definitions and outcomes.

Since the thesis is limited to the study of one particular compound, CFCs, and industrial activities in relation to the ban of this chemical, the time frame is described in a somewhat arbitrary way to take into consideration the differing contexts influencing each application of CFCs. Institutional/industry history regarding how long the CFCs have been used in each production system as well as in the time frame given to phase out the use of the chemical are decisive in setting the time frame in the description and analysis of each industrial application of CFCs. In general the descriptions will be in chronological order, though many activities and events overlap and interact with each other. We fully understand and acknowledge that we can only capture part of the complexity and dynamic involved in the change processes under study and the events may appear simpler than in reality. In the analysis the time frame is even more blurred since we sometimes concentrate on phenomena pertaining to multiple time periods. To simplify, we use "phases" to focus attention on dynamic aspects of the change processes.

The industrial system - a network of relational couplings and technological interdependencies

The analysis of the case of CFCs is framed in the context of industrial organization and change. The organizational and technological resources employed and the functions and activities performed by a firm are seen as interdependent with other firms who are part of the same industrial system. The exchange relationships between the industrial actors govern the production system which, in turn, is formed by production and marketing activities that employ, transform and develop resources, which in turn influence the connections and exchanges between the actors in the network (see Figure 4:3).

When studying change in industrial networks we look at changes in the exchange relationships among actors, changes in activities performed, as well as at changes in the resources used or employed in production. Separating the exchange activities performed by the actors from production resources and processes will give us greater precision in the analysis of the forces at play. Industrial actors are usually tied to several production systems as well as to different networks of actors which often creates tensions in on-going change process. Also, specific resources in a production system could be used in multiple ways and span many actors that do not necessarily have exchange relationships with each other. For example, the production system involved in the manufacturing and marketing of CFCs spans many industrial networks of exchange relationships, which in turn, in their specific deployment of the CFCs, are tied to several other production systems with different logics and actors. The network approach is therefore quite useful in helping to distinguish between tensions and forces pertaining to the resources employed in the production system (for CFCs in our cases) and the exchange activities connected to the actors involved in efforts to phase-out CFCs, and the inter-relationship between them.

In line with Johanson & Mattsson's model (1992) of an industrial system the distinction and links between interdependent "building blocks" of the industrial system can be illustrated as in figure 4:3 below.

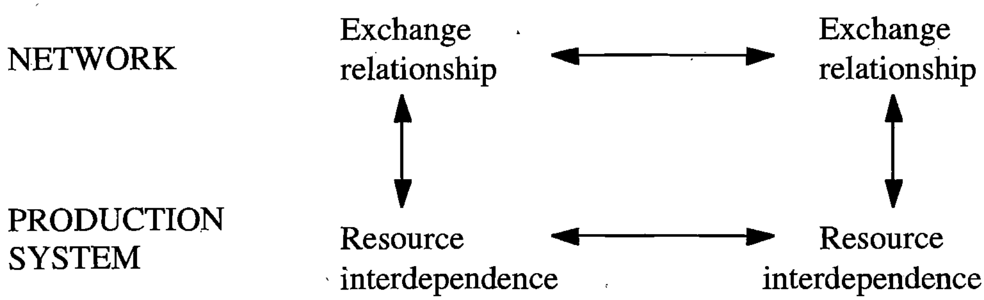

Figure 4:3: Interdependencies in the industrial system (source: Johanson & Mattsson, 1992:209)

This distinction between exchange activities performed by the actors and production resources and processes of the production system is useful, and in our analysis we set the industrial system in a broader institutional context. After arguing for the importance of understanding the institutional contextual influences in industrial systems, we refine the distinction between social and production systems, informed by our institutional context, and operationalized by relative degrees of "couplings" among actors and degrees of technological interdependencies among their production systems. We further operationalize this perspective by focusing on couplings and interdependencies relating to the product (CFCs) and production technologies of the users of CFCs. Examining the relative stability of these technological interdependencies and social couplings in relation to forces for change will help us to get a better understanding of the logic behind change patterns - or how logic develops in the course of change.

Industrial systems in institutional context

In addition to interdependencies among actors and resources, the industrial system also includes institutions and institutional rules that frame, influence, and support the system. The industrial system can be placed in an institutional context, or setting, as in figure 4:4 below. Johanson & Mattsson defines the institutional setting as the "social, cultural legal, political and economic conditions for industrial systems influencing actors' values and "world views"", (1991:266).

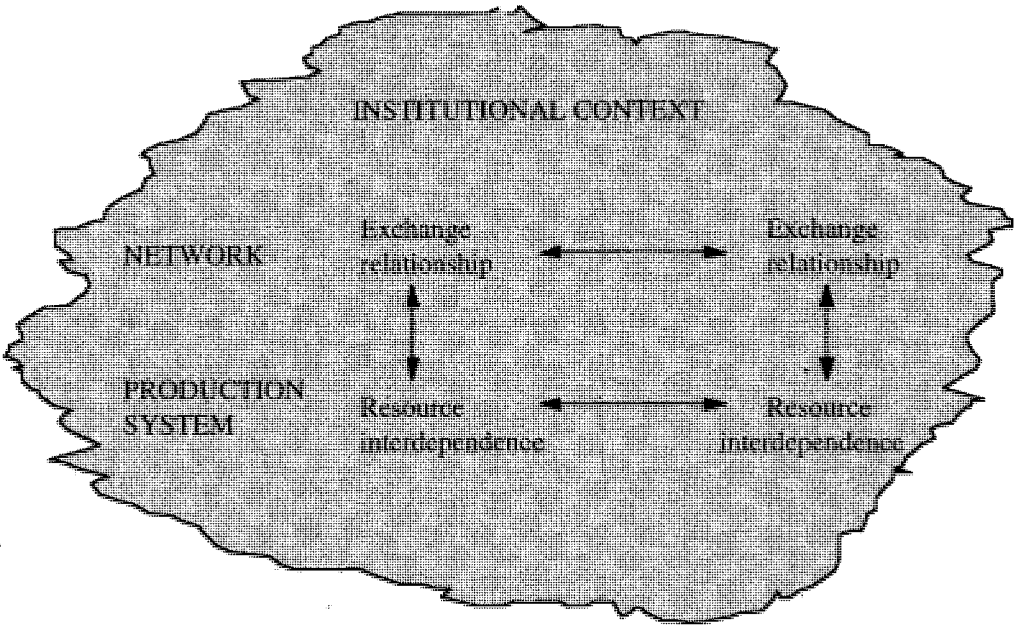

Figure 4:4. The industrial system embedded in an institutional context. Adapted from Johanson & Mattson, 1991.

The institutional context is as much a part of the interdependencies in the industrial system as the technology used. It is important to consciously account for the roles and influences of institutional contexts in industrial systems when analyzing industrial change. In the case of CFCs, institutions played an important role both with respect to inducing change via the implementation of regulations (rules) regarding the usage of CFCs, and in the means by which these rules were operationalized and interpreted by industry institutions, such as trade associations, and large, tightly coupled users of CFC products.

The industrial system consists of a fabric of interdependencies between actors and resources. Change can therefore theoretically be influenced by the degree or strength of these interdependencies. But there also exist less visible elements, for example norms and beliefs, that arise from such interdependencies and play an important role in the direction and outcome of change processes. In the network approach the intentions, strategies and views of the actors are often mentioned, to take account of the interaction and action that takes place in networks. These variables (actor intentions, strategies and views) are of course subjective and usually "measured" indirectly by analyzing the interdependencies in the network structure, or by studying the behaviors of the actors, or by taking at face value what actors relate to the researcher as motivations for their behavior. We consider these to also be a part of an institutional context as supported by Weick's (1979) notion of laymen "network theories". Thus, we suggest that the institutional context is both social-organizational (consisting of trade associations, government organizations, historical relationships, etc.) and socio-cognitive consisting of rules, norms, routines, beliefs, lay theories, etc.

These institutional elements and processes are difficult to analytically handle in a straightforward way. Following Weick (1976, 1982) we suggest that looking at the degree of relational couplings in comparison to production interdependencies will help us understand and describe change in industrial systems. Degrees of relational couplings viewed in the context of and in relation to production system *interdependencies offer an operational characterization of the industrial system context.*

Industrial system interdependencies - Relational couplings and production system interdependence

As noted in Chapter 3 loose coupling is evident when elements (e.g. individuals, sub-units, institutions) affect each other suddenly (rather than continuously), occasionally (rather than constantly), negligibly (rather than significantly), indirectly (rather than directly), and eventually (rather than immediately) (Weick, 1982). The network approach suggests that production system interdependencies significantly influence relations between organizations in a given network (via degrees of technological lock-ins and path dependencies, for example). By combining these operational definitions of loose/tight couplings with characteristics of production system interdependencies we operationalize a framework for characterizing *industrial system interdependencies* used to analyze our cases, and present it in Figure 4:5.

In each cell in the matrix presented in Figure 4:5 there are four operationalizations of the industrial system interdependencies. The top two points in each cell describe production system interdependencies and the lower two points in each cell describe relational couplings. The top row of the matrix presents operational descriptions of high, and the bottom row low, degrees of production system interdependence. The left column of the matrix presents operational descriptions of loose, and the right column tight, relational couplings. Diagonal cells thus present high-loose/low-tight & low-loose/high-tight operational descriptions of production system interdependencies and relational couplings.

Production System Interdependence	Loose	Tight
High	High degree of integration of production system & products Relatively high degrees of technical co-ordination Fewer standardized routines and activities among actors Links between actors tend to be around technical co-ordination issues, are more sporadic than continuous, and indirect.	High degree of integration of production system & products Relatively high degrees of technical co-ordination Many standardized routines and activities among actors Links between actors tend to be around technical co-ordination issues and to be continuous and direct
Low	Low degree of integration of production system& products themselves Technical change requires little co-ordinationamong actors Very few/no standardized routines and activities among actors Links tend to be sporadic and often indirect	Low degree of integration of production system& products themselves Tecnical change requires little co-ordination among actors Few standardized routines and activities among actors Links are continuous and direct

Relational Couplings

Figure 4:5 Industrial System Interdependencies

A tightly coupled industrial network is characterized by a strong, stable connectivity with many standardized routines and activities between few actors, usually. Change may be quick and forceful if induced by the actors in the network since the adaptability and coordination between the actors already in the network is facilitated by the existing links. But change might also be difficult in situations where all actors have to change simultaneously or it might be resisted if it threatens existing relationships or technologies. A tightly coupled network may also be "insulated" from external pressures to change if the control is centralized and there are few links or possibilities to adapt to variations in local demand.

A loosely coupled network is characterized by numerous actors with few connections that are less restrained and interdependent to that of a tightly coupled system (Andersson, 1996). A loosely coupled network is more open and flexible to change in that it has many links to "external" actors. But change might be difficult if a system-wide change is required rather than a local adaptation or change. Since few routines and standardized activities exist between the actors in a loosely coupled system, a coordinated change will take longer time or require the system to change towards more tight couplings. If the production system is highly interdependent, the loosely coupled system may increase its capability for to system-wide changes - for example regarding production technology shifts.

The concepts of tight/loose couplings and productions system interdependencies will be used in our description and analysis of the three different applications of CFCs. Each CFC application will be analyzed with regard to stability and change over time in actor relations, technological interdependencies, and interactions with institutional contexts. We will look at different patterns of change with regard to changes in tightness and the degree of lock-in in the relational and production systems.

Institutional organizational theory is also used in our analyses to support the influences of norms and beliefs in change processes. This thesis suggests *when* and *where* we should expect to find strong/weaker influences of norms and beliefs (socio-cognitive institutional influences) in change processes and relates them to outcomes observed. In particular, we adopt and modify the metaphor of social "inertia" in influencing the forces, direction and outcomes of the change processes. In general, it is proposed that the greater the social inertia the more difficult it is to change industrial logics of how production and market systems "work." Social inertia is studied and analyzed at both the meso-industrial network level (inter-firm relations and production system interdependencies) and at the macro-institutional level (rules, problem definitions, and their normative interpretation, for example). We will attempt to describe institutional (macro) forces working on the actor (micro) level, such as the pressures toward adopting solutions in a specific industrial network which lead to either isomorphic (homogeneous) or plurimorphic (heterogeneous) outcomes.

Based on the earlier theoretical discussions we anticipate that social inertia exists with regard to accumulated adjustments and interconnections in the technological system. The more complex and interrelated the technology, the greater the social inertia to hold to existing practices is likely to be, and therefore the greater the difficulty in changing firms' behavior in the system.

We also expect and examine how social inertia in the relational system influences change patterns. The number and stability of relationships in a network/field will influence the direction of change as well as the relative closeness of relationships. We anticipate and examine the extent to which networks with few, stable and close relationships (tight couplings) have a greater degree of social inertia, and thus, are expected to be more resistant to change than a network with loose couplings.

We argue that institutionalization processes, or processes of organizational patterning and conforming to their social environment are important in order to understand the direction and patterning of ecological industrial change processes. For example, formation of norms in society at large towards "zero-emissions" will likely influence a firm's choice towards or away from emission-free technologies or activities. These normative pressures will be reflected in the production system and influence network relations, for example in terms of common technological development efforts, or in changes in positions of network actors resulting from compliance with or neglect of such norms.

We also believe recognizing isomorphic pressures (homogenization in the field) are important for our understanding of the direction of industrial change processes towards sustainability. For example, the environmental management system ISO 14001 has rapidly diffused and evolved as a strong norm in Swedish industry. 60% (Belz, 1997) of all large Swedish firms have adopted the standard which will likely influence the direction of sustainable ecological change in industry as the licensing process continues to diffuse in the industrial network.

Isomorphic pressures are of three main types, mimetic/imitative, coercive, and normative (as presented in the previous chapter). Mimetic/imitative isomorphism refers to organizations adopting, or mimicking, practices, technologies, structures, etc., used by other organizations when uncertainty exists about the outcome of an activity or a behavior. Coercive pressures stem from an organization's legal, political, cultural, professional, educational, and occupational environment. Such pressures can be felt as force, as persuasion, or as invitations to join in collaboration.

Another important process we will examine in our cases is that of structuration. Structuration is an important concept in our model to understand the direction of the change process towards environmentally more apt industrial systems as outlined in figure 4:1. As described in Chapter 3, in the network approach structuration describes the process of elaboration of existing activities and resources, usually within established exchange relationships, to create change. Structuration is contrasted by, but does not exclude, heterogenisizing where change processes are characterized by new ways of combining (new or existing) resources and activities, often involving change in network relationships as part of the process or as a result (Håkansson, 1992).

In the institutional approach structuration is a process by which options become constrained and systems of interaction reproduce themselves. The guides for structuration lie in the actors' perceptions of what options are viable taking into account other organizations competing for resources, customers, political power and institutional legitimacy, etc. Four indicators/forces of structuration were presented in Chapter 3: 1) an increase in interaction of organizations in a field; 2) the emergence of defined inter-organizational structures of domination and patterns of coalition; 3) an increasing information load with which organizations within a field must contend; 4) the development of mutual awareness among participants. These indicators are compared descriptively (if not measured empirically) across each of our cases in relation to their different outcomes.

In the analysis of structuration, the institutional approach places focus on the relationships and perceptions of actors, while the network approach primarily focuses on the more tangible activities and resources that are elaborated during change processes in a network of exchange relationships. The institutional approach also focuses less on the exchange relationships between all actors in a field and is more interested in the structuration of the relationships between organizations that compete for the same customers or input resources. We think it is fruitful to combine these network and institutional approaches in looking at structuration processes, though we focus a bit more on the institutional approach. The network approach allows a broader set of actors to be included, which might be crucial, in the study of ecological change processes. The activities and resources employed are used as a selection variable for choosing actors for study. But it is the institutional approach that brings our attention to the influence of "outside" actors, institutions, norms, and cultures which might influence a given change process. These are influences that a given actor in a focal net (as selected by the network approach) may not have direct ties to, but nevertheless are important in the creating or defining of norms and beliefs inherent in an institutional context that influence paths of industrial ecological change.

From analytical framework to empirical observations

In this chapter we have re-captured and further defined the main variables that were discussed in chapter 3 and that we will use in the analysis of the CFC-case. The following chapter will broadly describe three different industrial processes of change resulting from the regulation of CFC. In chapter 6 an analysis of the case will follow, which ties our framework to the case and our main purpose to "understand .... change processes involved in solving .... ecological problems... at multiple levels .... within.. industrial settings.

Part III CHANGE PROCESSES TOWARDS ENVIRONMENTALLY SUSTAINABLE SYSTEMS

Chapter 5. The case of replacing Chloroflourocarbons - achieving change and preserving stability

This chapter presents the case of the regulation of Chloroflourocarbons. We begin by presenting a brief, general background to the underlying environmental problem raised by CFCs and the political processes leading-up to their international and national regulation. The "case" itself is comprised of three different applications of CFCs. We present these three applications describing each in terms of industry response to the regulations involved and the change processes leading to a total phasing out of CFCs.

Background

In 1988 the Swedish Parliament voted in favor of a proposition for the phasing out of the use of CFCs in all product and production applications before 1995. The 1988 Swedish regulations followed on from regulations adopted in Sweden in 1979, banning the use of CFCs as a propellant in aerosol packaging, and an international agreement negotiated in 1987 by UNEP, the United Nations Environmental Program. The 1987 UNEP agreement capped CFC consumption at 1986 levels and outlined a decrease by 50% of those levels by 1999. These regulations and the UNEP agreement followed the discovery of the role of CFCs in eroding the ozone layer.

As an important instance of an attempt to solve a serious environmental threat, we chose to study the change processes of three industrial networks involved in replacing CFCs in their products and in their production system.

The CFC case presents and describes some of the key actors involved in finding alternatives to CFCs in three different industrial applications. The applications include the use of CFCs: as a refrigerant and as a blowing agent in household refrigerators; a blowing agent in flexible foams used in furniture and automobiles; and as a cleansing agent for electronic products. The actors are from the chemical industry, major appliances industries, flexible foam manufacturers, electronics industry, as well as governmental bodies and non-governmental organizations, NGOs, (e.g., The Swedish Federation of Industries).

Protection of the natural environment

The problem as to how to deal with environmental pollution has increasingly come into focus for the general public, industrial managers, and policy-makers. Reports on oil spills, seal deaths, freshwater poisoning, reduction of natural resources, emission of harmful gasses, discharge of heavy metals and harmful chemicals into rivers, lakes, and seas, are seen with increasing frequency around the world. With the increasing burden that expanding populations and increasing industrial activity associated with them place on nature, and with our growing knowledge of the many different sources of environmental impact associated with industrial and population growth, the pressure on policy-makers and industries to take responsibility for reducing or minimising environmental disturbances has intensified.

In the area of environmental protection, many nations now take governmental action, as well as inter-governmental action through UN and other international organizations, in order to formulate and implement national and international policies. Accordingly, many regulatory laws and rules have emerged and evolved. Early environmental regulations often focused on industries' emissions into the air or discharges into water. Today there is an increasing focus on the whole system of pollutants and therefore an increasing pressure on industry to take responsibility for environmental protection throughout a product's life cycle - from choice of raw materials to a product's final destruction.

These pressures instigate new challenges and opportunities for industrial development. As well as integrating environment awareness into everyday business, it is also a matter of thinking "green" earlier in the strategic planning stage. Decisions regarding plant locations, the materials used in product packaging, and how to re-cycle or limit waste production when the product is disposed of, will likely increase in importance for consumers and other stakeholders. Since most businesses do not have control over the complete chain of activity from raw material to the use or final consumption of the product, individual actors will face new challenges of co-ordinating and controlling whole networks of organizations. Meeting these challenges as well as challenges from environmental policies implemented by national and international governmental institutions will likely result in structural changes.

Replacement of Chloroflourocarbons in industry

<u>Chloroflourocarbons and their related environmental problems</u>

Chloroflourocarbons and Halons comprise a group of widely used chemicals that, when released into the stratosphere, are today considered to be one of the most important causes of the ozone layer eroding. In the stratosphere, located 14-42 km above the earth, a layer of naturally occurring ozone made of heavy oxygen molecules filters most of the sun's dangerous radiation from reaching the earth.

CFCs are synthetic compounds that occur in both liquid and gas forms. They consist of hydrocarbons where some or all hydrogen atoms have been artificially replaced by chlorine and fluorine. These compounds offer some appealing advantages for use in products and production processes. For example, they are free from color, almost odorless, non-combustible, and have a low boiling point. These characteristics explain their wide usage in the manufacturing of everything from foam coffee cups to furniture cushions and refrigerants.

CFCs are considered to be relatively harmless at the terrestrial level. However, the problems caused by CFCs occur when they are released into the stratosphere. CFC emissions occur throughout their own lifecycles: during their production; in their usage to manufacture other products; in the consumption and service of the products containing CFCs; during the disposal or destruction of products containing them. Ultimately, CFC emissions occur during transportation, storage, and manufacturing of all value added chains of which they are an ingredient. As these compounds rise into the stratosphere the sun's ultraviolet radiation breaks apart molecular bonds inherent in the CFC compounds at lower levels. That is, ultraviolet radiation breaks down the CFC compounds which "releases" separate chlorine atoms into the stratosphere. These chlorine atoms attack heavy oxygen molecules found in the stratosphere. These heavy oxygen molecules are a natural occurring filter for dangerous ultraviolet radiation (see Figure 5:1 below). Each chlorine atom "survives" from between 75-150 years, and in this time can destroy up to 10 000 ozone molecules before finally dissipating.

Without protection provided by the ozone layer, the sun's ultraviolet radiation easily reaches harmful levels. Over exposure causes increases in the frequency and severity of skin cancers, eye cataracts, and even crop damage. According to measures conducted between 1969 and 1986, the ozone layer in the northern hemisphere had on average decreased by 3% over that time period. The emissions of CFCs during the 1980s were also estimated to be responsible for 25% of the global greenhouse warming (UNEP, 1987).

CFCs were invented in the early 1930s by Thomas Midgley Jr, a researcher at General Motors who was asked to find a better refrigerant for GM's Frigidaire division. Midgley introduced CFC as a non-toxic coolant to replace toxic ammonia, methyl chloride and sulphur dioxide in household refrigerators. CFCs were considered to be completely safe because of their properties of not reacting with other substances and being relatively stable. Since their invention CFCs are found in a variety of applications. CFCs have been sold under a number of trade names such as Freon, Frigen, Arcton, and Isotron, and were commercially produced in the late 1980's in five different qualities/compounds.

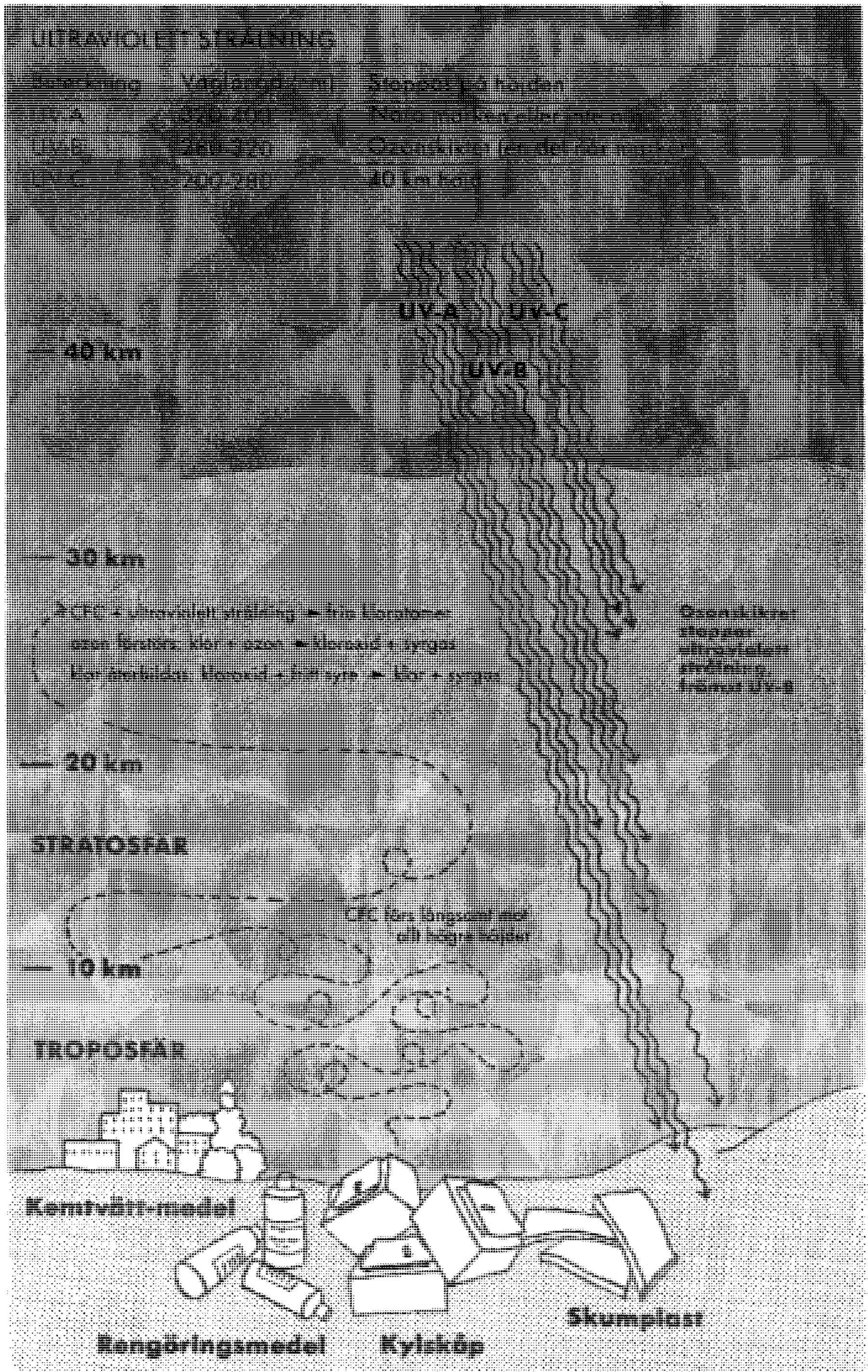

Figure 5:1: The Ozone-CFC Relationship

Source: Governmental proposition 1990/91:90, part A p. 13. From a drawing by Hans Nilsson.

Production

The world production of CFCs was about 1 million metric tons in 1987. A small number (10-15) of large chemical producers, including Du Pont, Allied-Signal, ICI, Hoechst, and Asahi Glass, accounted for the major part of the production. The largest producer was Du Pont who alone accounted for 25% of world CFC production.

In 1987, at the time of the ratification of the Montreal Protocol, no CFCs were produced in Sweden. But in 1986 there were many users who had a total net use (including import of products containing CFCs) of 5 000 metric tons. The main areas for CFC use in Sweden were as a foaming agent for soft- and hard-foam products, and as a refrigerant in refrigerators and refrigerating plants. Other usage areas included use in heating pumps; use as a solvent to clean debris and excess solder for products in the electronic- and mechanical industries; use as a solvent in the dry cleaning industry; use as a propellant in aerosol sprays; and applications for sterilizing medical equipment.

Discovering an ecological threat

In the early 1970s the first concerns about ozone depletion were related to the high-flying supersonic transport aeroplanes that the U.S., Britain, and France planned to build. A German scientist theorized that the exhaust would catalytically consume ozone (Crutzen, 1970 as cited in Litfin, 1994). As a result the U.S. Congress voted to terminate the funding for the aeroplanes in 1971, much to the dismay of France and Britain.

At the same time several programs to study the potential impact of space vehicles were started. With this, focus shifted to the chlorine in the exhaust of the planned space shuttle. NASA, the National Aeronautics and Space Administration, was at the time spending one third of its budget on the space shuttle. NASA took immediate action to change focus to other sources of chlorine. NASA convinced the U.S. Congress to give funding to them to study stratospheric ozone and quickly established itself as the most important authority on ozone. NASA spent $15-20 million annually during the years of international negotiations. That was approximately 70 percent of global research funding on the stratosphere (Litfin, 1994).

In an article in Nature in 1973 a British scientist published the results from a study of the concentrations of CFC-11 in the atmosphere. He estimated the concentration to be roughly the same as the global cumulative production, indicating that the compound was indestructible (Lovelock, 1973). One year later Molina and Rowland published their seminal paper in Nature arguing for an immediate ban on CFCs used as aerosol propellants. They pointed-out the connection between the emissions of CFCs and the harm to the ozone layer. Molina and Rowland (1974) hypothesized that CFCs would be un-reactive in the troposphere. The chlorine atom originating from a CFC molecule would be resistant to the sun's ultraviolet radiation until it reached altitudes as high as to the stratosphere. At this altitude a process of breaking-down of the molecular bonds occurs, thus releasing the chlorine in the stratosphere itself.

The third influential event in regard to CFCs and their impact on the ozone layer was the discovery of the ozone hole above Antarctis. Since the British Antarctic Survey announced the discovery in 1985, ozone depletion has been reported in both the southern and northern hemispheres, but probably most severe above the Antarctis with a 50-60% depletion.

Controlling an ecological problem

The first regulation of the use of CFCs came into effect 1979. Based on the scientific discovery of the hazards caused by CFCs, together with pressure from the general public, USA, Canada, Norway, and Sweden introduced national policies banning the use of CFC as a propellant in aerosol sprays. At the same time Japan, Australia, and the Netherlands introduced programs to reduce the amount of CFCs used in aerosol packaging. In 1980 the European Economic Community, EEC (now European Community, EC) placed a production cap on the two most commonly used CFCs: -11 and -12 .

In the mid-1980's data on the depletion of the ozone layer instigated tougher regulations aimed at controlling the emissions of CFCs. The policies adopted earlier were evaluated at various workshops arranged by the UNEP. Production of CFC-11 and -12 for use in aerosols declined, but productions and use actually increased for other applications resulting in a net increase in overall CFC-11 and -12 production by the mid 1980s. The failure to achieve a reduction in CFC use was attributed to the low number of nations imposing limits on the use as well as the focus on one single usage area -- the use of CFCs as an aerosol propellant. Thus, limiting the ban to one usage area left other CFC applications to occur unhampered, and as such did little to stimulate innovation to develop CFC substitutes. Furthermore, in the EC the maximum production level in 1980 was limited to 480 000 tonnes, considerably *greater* than actual production, while CFC output remained fairly constant.

Besides failing in reducing the amount of CFCs used, the policies failed also to signal to manufacturing and user industries to develop alternatives. On the contrary, some of the existing users expanded their use of CFCs; e.g., refrigeration, foam, and electronics industries; and new usage areas were developed during the period following the first restrictions and regulations.

Negotiations for an international agreement to restrict the emissions of CFCs began at a UN meeting in Stockholm 1980. Those negotiations resulted in an agreement in principle on co-operation to protect the ozone layer. The Stockholm meeting was followed by years of discussions and negotiations along with alarming reports on the erosion of the ozone layer and pressures from environmental groups and the public to ban CFCs. But, up until 1985, when the issue recaptured interest due to the discovery of the Antarctic ozone hole, the markets for CFCs expanded into new applications and production increased (see Figure 5:2 below). The ozone hole discovery increased public demands for controlling CFS emissions. Negotiations between political institutions and industry to reduce the use of CFCs intensified. As a result a UN treaty was signed by 24 countries in Montreal in 1987 (UNEP, 1987). Under the agreement, consumption[1] of the most commonly used CFCs was to be capped at 1986 levels beginning in 1989, and gradually reduce to 50% of the 1986 level by 1999. The parties to the agreement agreed to report annually on the consumption.

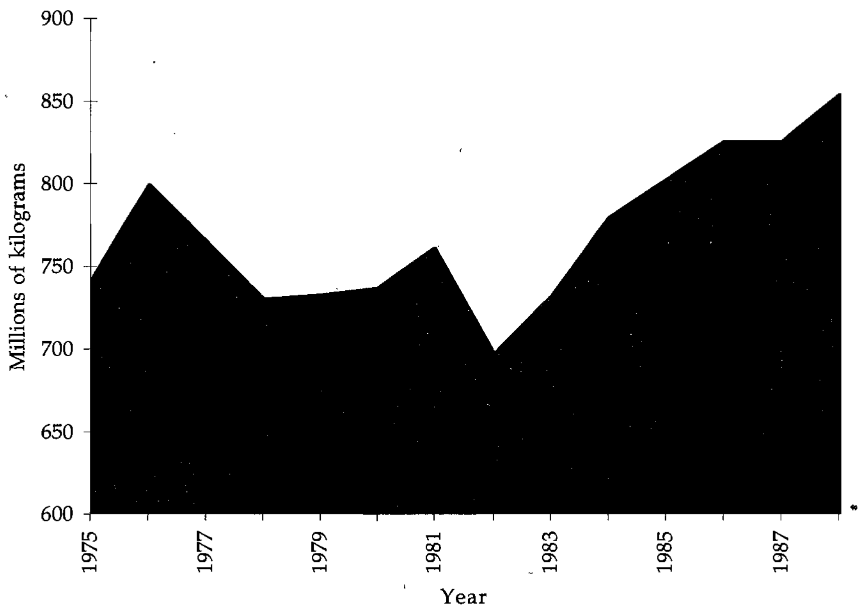

Figure 5:2: CFC 11 & 12 Production
Source: UNEP, 1987

Prices of CFCs increased in response to the supply restrictions introduced in the Montreal Protocol. The prices of CFC-11 increased from USD 0,61 per pound in early 1989 to USD 0,90 a year later. The most commonly used CFCs (11 and 12) in refrigerators were commodity chemicals, marketed by most of the chemical companies involved in the production of CFCs. That is, they

[1] Consumption is defined in the Montreal Protocol (UNEP, 1987) as production + imports - exports in bulk form, i. e., pure CFCs.

were sold in large volumes at low prices. Most of the CFC substitutes offered by the chemical industry were expensive specialty chemicals, characterized by complex production processes and low production volumes.

The Montreal Protocol was revised at the 1990 UNEP meeting in London and in the 1991 meeting in Copenhagen which speeded up the phase-out of CFCs. More than 70 countries had ratified the agreement in October 1991. The UN-coordinated international work also includes the formation of committees to co-operate on technical and scientific matters in relation to the ozone depletion and CFC phase-out. Regulatory as well as industry bodies participate in these committees.

The Swedish CFC phase-out plan

As noted earlier, no CFCs were produced in Sweden, but in 1986 Sweden used some 5 000 metric tons. About 50% of Sweden's CFC usage was either as refrigerant or as blowing agent in the production of hard and soft foam plastic products. In 1987, the Swedish Government explored the possibility of accelerating the phase-out of the use of CFCs at a faster rate than proposed in the Montreal Protocol. Evaluations for all applications of CFCs were made in an attempt to establish what available substitutes there might be, and the time needed for migrating to their use. Industrial trade organizations from the different application areas, together with some of the larger industrial users of CFCs, were involved in those investigations and evaluations.

A submission system normally used in policy-making processes in Sweden was followed, but industrial actor participation was encouraged at earlier stages of the policy process than would normally be the case. The resulting regulation was the first of its kind in Sweden to include industry in the early stages of the regulatory process. Some of the participating firms were also called to hearings at the Department for Environmental Affairs where they presented their views on the probable impact of proposed regulations on their business.

Sweden was the first country to adopt a national phase-out plan in 1988 with a gradually restricted use on a yearly basis with a complete ban beginning in

1995. The Swedish regulation embraced nine usage areas with different timetables for each area. These timetables resulted from negotiations with industrial actors and trade organizations. Close consideration was given to both the difficulties involved in finding CFC substitutes and the amount of CFCs used for a specific application.

CFC manufacturers and activities towards finding solutions

As mentioned earlier, the world production of CFCs in 1987 was about 1 million metric tons. A small number (10-15) of large chemical producers with global activities, (including Du Pont, Allied-Signal, ICI, Hoechst, and Asahi Glass) stood for the major portion. 40% of world CFC production was produced within the EU. For these producers, CFCs basically represented a relatively small fraction of their total activity, a small group of rather simple and relatively undifferentiated commodity products in a much larger portfolio of chemicals.

CFC manufacturers were the first to experience pressures to find substitutes. Prior to the first regulation in 1979, the chemical industry itself was opposed to a ban on the use of CFCs. In a 1975 advertisement in *The New York Times* (Moore, 1990), Du Pont urged for a delay of the ban. It argued that more research was needed to develop "definite information" about the CFC/ozone relationship. During the period following the first regulations, uncertainties existed regarding the exact relationship between the CFC emissions and the ozone layer depletion. The chemical industry organized to prevent further regulations. Industry actors argued that the scientific evidence was far too uncertain to justify further regulations, and called for additional research to justify any further government action.

After a short period the search for alternatives and the research on substitutes were discontinued by CFC manufacturers. The search for substitutes halted for two main reasons: a) the uncertainties of the CFC/ozone relationships made it clear that no *immediate* new regulation was forthcoming, and b) possible candidate substitutes were relatively costly and there was a perceived lack of business opportunity resulting from such costs.

However, considerable research and a continued growing negative public opinion, as noted earlier, created a new climate for regulating CFCs, and by the mid 1980s new regulations appeared (e.g., those stemming from the discovery of the hole in the ozone over Antarcticis in 1985 and the Montreal Protocol of 1987).

As a response to these new bans on selected CFCs, the chemical industry in 1987 selected two compounds, Hydrochloroflourocarbons (HCFCs) and Hydroflourocarbons (HFCs), as the most favorable substitutes to develop. HCFC and HFC compounds were selected since they promised less ozone depletion potential, but kept the benefits of the CFC compounds, as well as being perceived to be the options "most likely to succeed"[2]. Reservations about introducing HCFCs, with their high level of chlorine and relatively strong greenhouse warming potential had been expressed by policy makers but were ignored. HCFCs were also mentioned as compounds likely to be banned in the future. At the time the chemical industry took these decisions, HCFCs and HFCs had undergone practically no testing in end-use applications.

Collaborative activities were started within the chemical industry to test and further develop these substitutes. Due to long development cycles, with toxicity tests, end-use application tests, and large investments in production facilities, the chemical industry estimated it would take five years to commercialize substitute compounds. Characteristic to the product development process in chemical firms is that new products develop through two main lines: (1) application related activity where researchers get a task to solve a problem with an existing molecule (for example the CFC problem); and (2) new findings in research laboratories where the task is to find applications. The process is usually long and research intensive with

2 Statement of Mr Heckert, chairman of the board at Du Pont, in a letter to a U.S. EPA administrator, March 1988, (Hoffman, 1990).

rigid toxicity testing to detect dangers to human health, and lately, environmental hazards.

Governmental and supranational organizations engaged in encouraging industrial collaborations and research activities. For example, the US Environmental Protection Agency, EPA, supported industry co-operation by helping industries to obtain exemption from antitrust laws for joint research, as well as itself being active in the search for substitutes. In 1988, leading US, European, and Japanese chemical firms jointly announced a collaboration project intended to avoid duplication of research effort as well as shortening the completion of toxicity tests.

Activities in the search for alternatives to CFCs - Connecting developments with users

Theoretically there were numerous ways of reducing CFC emissions. CFC manufacturers could stop manufacturing CFCs and develop and manufacture alternative chemicals. Users could shift to products not based on CFCs. Other existing chemicals could be used in products using CFCs. Production methods using CFCs could be supplemented by, for example, recycling or more efficient use than those used. More careful use and reducing CFCs through service and repair of products could reduce emissions. Alternative products or methods could be used in post-production stages. And CFCs could be collected for destruction at the end of the lifecyle of products using them (i.e., refrigerators). But, increased international support for imposing limitations on the manufacturing and use of CFCs as well as the already instigated restrictions on their use, prompted CFC makers to invest in the search for less harmful substitutes.

European, American, and Japanese chemical manufacturers all invested in research to find alternatives to the CFCs. HCFCs, derived from petroleum distillates, and solvents made from citrus fruit rinds are two examples of compounds which were researched.

CFCs were at that time a straight-forward, stable commodity product. A search for substitutes called for large expenditures on research and development, rigorous toxicity testing, investments in production facilities, equipment and in markets to manufacture and market the substitutes. A variety of research projects on compounds that could replace or substitute CFCs emerged in the late 1980s. Du Pont developed HCFC-22. ICI worked-on CFC-134a and -123. Allied-Signal and Atochem formed an alliance to develop substitutes for CFC-11 and -12. Common to all the compounds was the lack of knowledge about their actual effect on the environment and the fact that it would take about five years of testing before any of them could be commercially produced and marketed.

Du Pont developed a substitute for the electronic industry that would be less destructive to the stratospheric ozone than CFCs. Unfortunately, the new solvent, 132b, was found to cause male rats to be sterile after exposure to the product. Du Pont decided to perform further research before making it commercially available. Some chemical companies developed new breeds of CFCs in the laboratory but at that time had not yet found ways of producing them on a large scale. Both Allied-Signal and Du Pont invested large sums to find methods for producing a chemical called HFC-134a, which contained no chlorine but had much the same properties as the refrigerants used in air-conditioners for cars. Unlike the conventional CFCs, which could be manufactured in a one-step process, HFC-134a would require at least two steps causing unwanted by-products in the manufacturing process. HFC-134a was also very costly to produce.

Another compound that was made commercially available was HCFC-22. It contained hydrogen which facilitated its break-down before it reached the stratosphere making it 95% less destructive on the ozone layer than standard CFCs. HCFC-22, despite being up to 50% higher priced, was gaining popularity as a coolant for commercial and residential air-conditioning systems. It also gained approval in the U.S. for use in fast-food containers. HCFC-22 was a good substitute for some applications. But because of some of its properties, like poor insulating qualities and low boiling point, it was unattractive as an alternative for the construction- and car industries.

HFA 124 was an alternative refrigerant that was produced by Du Pont in a pilot plant in New Jersey in the early 1990s. HFA 124 was a key component in several new compounds which potentially could replace CFC 12 and R-500 in many refrigeration applications. HFA 124 underwent toxicity tests and had an estimated 95% lower ozone degradation potential and 90% lower contribution to the greenhouse effect compared to existing refrigerants. HFA 124 could be mixed with other refrigeration media and could thus be used in refrigeration applications that originally contained CFC 114.

Du Pont also developed an alternative to R-500 refrigerant, which was used in de-humidifiers, coolers, and other medium-temperature refrigeration applications. The alternative was a mixture of HFC 22, HFC 152a, and HFA 124, with an estimated 90% lower ozone degradation potential and contribution to greenhouse effect compared with R-500. ICI intended to start production of AFC 134a at a new production facility in Los Angeles in the mid 1990s. It was intended as an alternative for CFC 12, and was to be marketed under the brand name KLEA. Also, the Du Pont Corporation announced on August 21, 1991, its decision to construct, in Corpus Christi, Texas, the world's largest plant for production of CFC substitutes. The production capacity was set at 32 000 metric tons yearly of the compounds HFC-134a and HCFC-124.

It was only the large chemical producers who invested in R&D to find substitutes. Smaller more specialized chemical companies also tried to develop substitutes. Petroferm, a privately held specialty chemical company in Florida, USA, developed a solvent to clean printed circuit boards. The compound, Bioact EC-7, was made of terpenes extracted from citrus fruit rinds. They have tested the compound together with AT&T on electronic products that are immersible in water during manufacturing.

The development activities among the CFC producers were spurred not only by demands from users and regulators but also by the threat of new competition. But once the strategic decision had been taken by the CFC producers to concentrate their efforts on the selected substitutes, a start was made on projects with end-users to test the new compounds.

On the user side, the search for substitutes was of high priority. In the white goods industry, Electrolux, Siemens-Bosch, General Electric, Whirlpool, Philips, Thomson, and AEG all invested in finding CFC-free alternatives for cooling and insulation. In the early 1990s, the large CFC users were testing how the new compounds could be adapted to current production technology and products. In the late 1980s and early 1990s Electrolux, which accounted for 12% of the CFC-use in Sweden, invested about SEK 20 million annually in development costs and employed 20 engineers and researchers full time, searching and testing substitutes for CFCs in its products.

A large variety of possibilities existed for finding alternatives to CFCs, depending on the application. It seems like the white goods- and air conditioner industries had the most severe problems finding a viable substitute. This is interesting since CFCs were first developed for these two applications.

The case of refrigeration - co-ordination among manufacturers and keeping the stability

The refrigeration application describes some of the key actors involved in finding alternatives to CFCs as coolant and insulation in refrigerators and freezers. The actors in this industrial network are from the chemical and major appliances industries, all with substantial international or global businesses. Electrolux, the single largest user of CFCs in Sweden, was the first among the world leading refrigeration firms to be legally pushed to address the CFC problem. Electrolux had no solution to the problem of finding a replacement for CFCs for its products, refrigerators and freezers, and was forced to take immediate action to solve it. In the beginning of 1993 full scale production of CFC-free refrigerators and freezers started in Sweden while implementation in Electrolux manufacturing plants abroad was accomplished over a two year period thereafter.

Refrigeration - historical and technological landmarks

Refrigeration technology was developed for storing and preserving food-stuffs, an activity that places the study of CFCs at the core of societal development. Early cooling solutions attempted to "preserve" cold temperatures or create cold storage environments. They relied on transportation and insulation. Cooling solutions to store and preserve eatables were found in early history in India and Egypt. There, evaporation cases (receptacles) were used comparable to the containers used today to keep butter from being spoiled. In 329 B.C. Alexander the Great installed large ice-cellars deep in the mountain to handle the provisions of food to the troops during the long siege of the fort in Petra (the "forgotten city" in today's Jordania). The Romans transported snow and ice from the Alps. In Pompeii the remains of cooling "bars" have been found which were cooled with snow and ice. Cooling mixtures of ice and saline, and a variety of saline solutions, were widely used during the 1500-1700 centuries and as a complement to the ice-cabinets during the following centuries.

Mechanical cooling process appeared for the first time in 1755 with the Scotsman W. Cullen's experiments in the evaporation of water with the help of a vacuum pump. But for cold storage of foodstuffs in households and grocery stores, the use of natural ice, (taken during the winter from frozen lakes, stored in sawdust, and sold by special ice companies), continued to be the most widespread method used long into the twentieth century. Ice was stored after the English model in insulated cabinets that created a cold environment for food. In Sweden the ice-cabinet was used from late 1800 into the first three decades of the 1900's.

The first refrigeration machines intended for households were developed during the early 1900s. They incorporated and extended technology and knowledge developed during the nineteenth century when the phenomenon of latent heat was explored. With expanding cities and industrial development came the need to preserve food for longer periods of time and the need for mechanical refrigeration grew. By the end of the nineteenth century refrigerating machines were used in several areas for food-preserving purposes. For example, breweries used them to cool their products while they aged. Meat packers used refrigeration in the handling and processing of meat. Others manufactured ice for sale of it to households. Cold storage services began to appear, and refrigerated transports became more common and less expensive. Though commercial refrigeration was widely available in the beginning of this century, it took almost another three decades before the production of refrigerators for household use began.

Some important developments following Cullen's machine:

1834 The American Perkins invents the compressor machine using ether as a coolant. The machines were very problematic because of frequent ether explosions.

1849 Gorrie in England invents the first cold-air machine.

1860 The Frenchman Carré launches the absorption machine using both liquid and solid absorption agents. In 1864 he improves Perkin's compressor and three years later he starts using H2N as a cooling agent.

1861 The Australian Mort and the Frenchman Nicolle construct the first refrigeration facility in Sydney, Australia.

1870 Linde in Germay develops a reliable compressor machine.

1876 The Frenchman Tellier makes the first transportation of goods in a cool storage room from United States to Europe with the steamship "Frigorifique".

1895 Linde develops oxygen apparatus for cooling purposes.

1903 The abbé Audiffren constructs the first completely hermetic compressor unit.

1908 The Frenchman Pollard defines the principles for the first thermostatic expansion valve that later is constructed by Delco Light Company in the United States.

1922 The Swedes Munters and von Platen invent the first cooling machine without moving parts.

1930 The Americans Midgley, Henne, and McNary introduce Chloroflourocarbon as a cooling agent.

1946 Large scale production of the hermetic compressor starts with the Tecumseh compressor taking the lead.

1955 Collins invents a commercial expansion machine for the production of helium.

1957 Philips in Holland introduces the oxygen absorption machine on the market.

1958 The Peltier effect becomes popular as a cooling process for smaller refrigeration needs.

Two methods emerged for household refrigeration: absorption- and compressor technologies. The first refrigeration machines used in Sweden stemmed from Linde's (1870) compressor machine. Linde experimented with compressing and expanding gas, which gave a refrigerating effect. The early compressor machines were expensive, not very reliable, and suffered problems caused by inadequate valves and leakage. To solve these obstacles the Swedish engineer Bengt Ingeström further developed the compressor. During the fall of 1920 the first valve-less machine was constructed and tested. These early constructions were solely based on the compressor technique but, only a few years later, Ingeström started development of

Careé's (1860) absorption machine. After several trials using different technological solutions, a patent was filed in late 1922 on a valve-less, absorption machine. To fully utilize the developments, a factory was needed and during 1922 a modern manufacturing plant was bought and AB Arctic founded.

In 1923, the two Swedish engineers Carl Munter and Baltzar von Platen, at the Royal Institute of Technology in Stockholm, had developed a refrigeration machine based on a closed system that worked without any moving parts (see figure 5:3 below for a photo of the inventors and their machine). It was designed to run continuously without any automatic controls. The refrigeration principle was based on the transformation of heat from a radiator to coldness using the absorption technique. The refrigerator used ammonia as a coolant, and could be run with the help of electricity or gas.

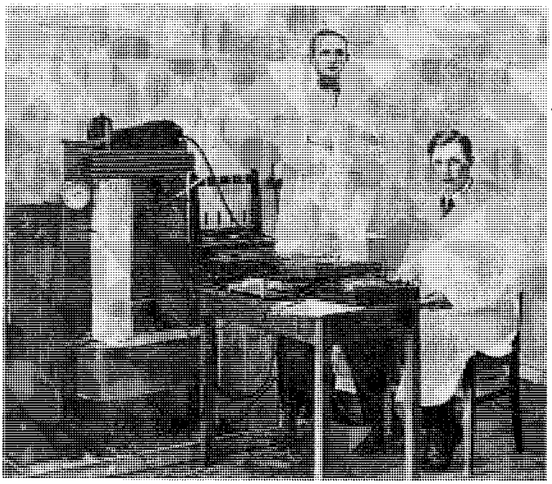

Figure 5:3: Photograph of Munter & von Platen and their refrigerator
Source: Electrolux

In June 23, 1923, an agreement was signed between Munters-Platen Refrigerating Systems and AB Arctic. The agreement gave Arctic the sole right to use Munter's and Platen's patents, inventions, and constructions in the area of cooling technology, within Europe, (except England and her colonies), the non-European countries around the Mediterranean, and South America. The development work that followed was substantial and the first refrigerator for households that could be manufactured on a larger scale was shown in February 1925.

The first refrigerator had yet to be put on show for the public when Electrolux acquired the right to manufacture the refrigerator according to the Munter- Platen system. Electrolux was at the time mainly producing and selling vacuum cleaners and was interested in expanding its product-line into a new promising field. Electrolux first received the rights to market the absorption machine in the parts of the world not included in the agreement with Arctic, which constituted about 4/5 of the world market. At the same time there were also negotiations with AB Arctic's founder, Ingeström, about integrating the two companies. In March 1925 they made an agreement on the Electrolux acquisition of AB Arctic's patent rights to the refrigerator in Arctic's district. AB Arctic was fully acquired by Electrolux later the same year. The acquisition brought well-needed money to the refrigerator project, and further developments could be achieved.

The first aim of further development was to replace the water-cooled machine with an air-cooled one. Munter and Platen's first machine was water-cooled which required both a water pipe and a source for heat, like electricity or kerosene. The first assembled air-cooled refrigerator was shown at Liljevalchs Fair in 1925 in Stockholm (see figure 5:4). Manufacturing on a large scale started in Arctic's plant in Motala paralleled with further development of the refrigerator system. Electrolux also adjusted the absorption machine for consumer needs and industrial production.

During the 1930s and -40s, the absorption machine was very successful. But increased demand for larger sizes and growing electrification of households led to the absorption machine being faced with a competitive alternative, the compressor machine. Around 1920 the compressor machine was largely used for commercial purposes, thus adapted for large refrigeration needs. For domestic refrigeration usage the compressor machine was still not developed to appropriate scale use in the household. For example, the compressor was sold separately from the compartment and the technology was not very reliable (frequent malfunctions and service needs). Frigidaire, founded 1916, was one of the larger companies involved in the refrigeration business and in 1919 General Motors acquired Frigidaire furthering its development and production of compressor machines.

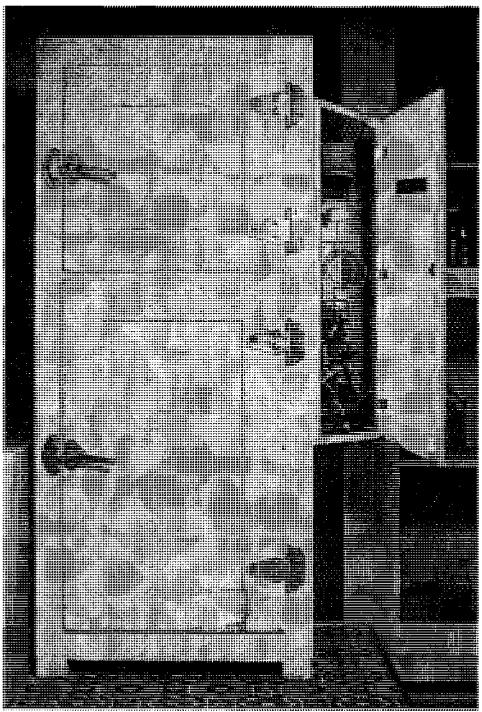

Figure 5:4: The 1925 absorption refrigerator
Source: Electrolux

By the 1940s, the refrigeration business in Sweden was dominated by Electrolux. However, with increased access to the compressor and absorption technologies several other firms entered the market. At that time the market for household refrigerators in the U.S. was dominated by four manufacturers of compressor machines: General Electric, Westinghouse, Kelvinator, and Frigidaire. Each of these were very large firms that had significant activity in the electric industry or some other major industry giving them substantial financial resources to engage in large-scale production and marketing of refrigerators.

<u>The entry of CFCs in refrigeration</u>

In the early 1930s Charles F. Kettering, the research chief of General Motors, asked chemists at GM's Frigidaire division to find a better refrigerant for compressor driven refrigerators. The chemists Midgley, Henne, and McNary quickly developed a series of synthetic refrigerants to be known as CFC's. The objective with the invention of CFCs was to find a stable, odorless, non-corrosive, and nontoxic replacement for the coolant gases used in refrigerators. The Du Pont Corporation and General Motors soon made an agreement that involved the technical development, production, and marketing of the newly invented CFCs. The development of the compressor machine as the leading technological solution, together with the properties of the CFC and Du Pont's decision to start industrial production of the compound, hastened CFC adoption by refrigerator manufacturers.

By the late 1940s, CFCs had become the dominant refrigerant used in refrigerators. Another milestone in the development of the compressor refrigerator was the 1946 start of large-scale production of the *hermetic compressor*. The hermetic compressor reduced the need for service, and the Tecumseh compressor took the lead in development and sales. Compressor technology became more reliable, relatively silent, efficient, and their compartments were smaller, which helped to increase their popularity. In the late 1950s demand increased for larger refrigerators for which compressor technology was even better suited.

One important trend-setter in the USA was Ramon Louis who designed many products in the 1950s including large American refrigerators. Absorption technology-based refrigerators could not easily adapt to these larger sizes. By the end of the 1950s compressor machine were the dominant technology used in refrigeration, leaving absorption machines to niche markets like recreational vehicles and hotel mini-bars.

With the advent of the hermetic compressor, most of the fundamental innovations (with the exception of automatic defrosting) in the design of the household refrigerator had been made. New features like temperature zones, flexible shelves, ice-makers, and lights, became part product differentiation strategies in a competitive market. These were incremental improvements not based on any major technological innovations in mechanics or physics.

In the 1960's, CFCs were introduced as a very effective ingredient in the insulation-foam used between the inner- and outer mantle of the refrigerator. This foam also had an important structural stabilizing function for the construction of the refrigerator.

<u>The Swedish market, network for refrigerators and the use of CFCs</u>

Approximately 450 000 refrigerators and freezers have been sold yearly on the Swedish market since the 1970s. They are sold as separate units of refrigerators and freezers, or as combination units. According to estimates made by the Swedish Environmental Protection Agency, Swedish households have refrigerators containing a total of about 5 000 metric tonnes of CFCs in their homes. Each refrigerator contained, in 1991, 0.1-0.2 kg of CFC-12 as refrigerant and 0.4-0.6 kg of CFC-11 in the insulation.

There are about 40 suppliers of household appliances in Sweden, most of them providing refrigerators and freezers. The market is largely dominated by Electrolux, which has 52% of the total sales of the appliance market. Electrolux's major competitors do not have any refrigerator or freezer production facilities in Sweden, but import them from their production units abroad, usually located in central Europe.

Electrolux AB

One of the first refrigeration firms to meet the demands on phasing-out CFCs was Electrolux, one of the world's leading manufacturers.

Electrolux was formed 1919 through a merger between the two corporations Elektromekaniska AB and Aktiebolaget Lux. AB Lux was formed in 1902 and manufactured a paraffin lamp for outdoor use. Elektromekaniska was formed in 1910 by Axel Wenner-Gren, who developed a Swedish vacuum cleaner to be sold following the American marketing practice of direct selling to households, backed by instalment financing. A few years after its inauguration, the company looked into extending the product range, which led to a co-operation in 1912 with Elekromekaniska AB in producing vacuum cleaners for households.

In 1925 Electrolux acquired AB Arctic (as noted above) which held patent rights to manufacture Von Platen & Munter's innovation the absorption refrigerator. The same year Electrolux launched the "D-fridge" on the world market. This first refrigerator was simple and functional. In 1927 Electrolux built plants in England and France for manufacturing of vacuum cleaners but later extended the production facilities to accommodate refrigerators. In 1928 Electrolux had grown to include five manufacturing plants, twenty subsidiaries, and 350 sales offices around the world, and Electrolux stock was introduced on the London Exchange.

The first built-in refrigerator was launched by Electrolux in 1930. It was shown at the 1930 Stockholm Exhibition. A fire destroyed the Electrolux manufacturing plant in Stockholm in 1936. This is an important event in the company's history as in combination with re-building the plant, a new central research laboratory was established with a department dedicated to refrigeration. In the late 1930s standards for Swedish kitchens emerged. Electrolux developed refrigerators fitting these standards and the concept of "the peoples refrigerator" was born, much in a Swedish style.

During World War II, refrigerator manufacturing slowed and refrigerator production at the Motala plant was replaced by the manufacture of steel fixtures. During the same period Electrolux started production of vacuum cleaners in New Zeeland and Australia and launched a new product, the kitchen machine "Assistant". By the end of WW II Electrolux added washing machines for the residential market to its product line by acquiring Bohus Mekaniska Verkstads AB (of Sweden).

After the war, Electrolux re-opened its activities in Germany and the production of refrigerators was located in Berlin. In the 1950s Electrolux continued its world expansion. In 1951 its first washing machine for households was marketed. In 1955 it started production of refrigerators in Argentina. Several new models were introduced and product design was elevated as an important factor in competition (see figure 5:5 below for a photograph of one of the 1950s refrigerators). In 1956 Electrolux launched its first freezer and first compressor operated refrigerator. A few years later Electrolux successfully engaged in exportation of absorption refrigerators for trailers (recreational vehicles and mobile homes) to the U.S. market. In the late 1950s the first dishwasher designed by Electrolux itself, was launched.

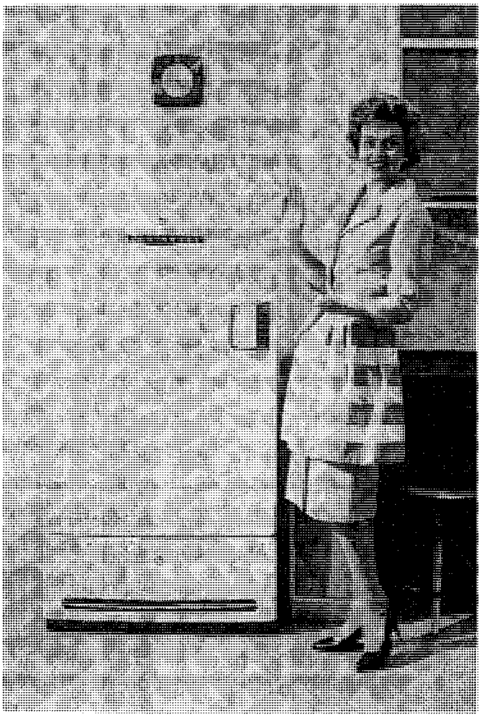

Figure 5:5: A 1950s refrigerator from Electrolux
Source: Electrolux

In the late 1950s sales of absorption refrigerators slowed and Electrolux was forced to make a strategic decision to switch over to large scale manufacturing of compressor refrigerators and freezers which had gained popularity over absorption technology. In 1962 Electrolux acquired ElectroHelios including new plants in Mariestad, Sweden, for the manufacture of compressor refrigerators. That acquisition gave Electrolux its own production unit and product- as well as production knowledge of compressor technology. Other important products included in the acquisition were stoves and appliances for industrial purposes.

Since 1964, Electrolux has acquired several manufacturers of both absorption- and compressor refrigerators. The most important ones were the acquisitions in the mid-1980s of Italian Zanussi and the U.S.-based, White Consolidated Inc. In 1991 Electrolux was the world leading manufacturer of absorption refrigerators and the third largest manufacturer of household appliances.

Product and Production design at Electrolux

At the time of this investigation the Design Group at Electrolux had a fragmented and diffused organization with departments located close to Electrolux production units and markets. The Group has five departments in Europe and three in the United States. There are also three Design Centers, two in Stockholm and one in Italy. All departments operate under the same strategy and they report to their local manufacturing and sales units as well as to the manager of the Design Group, who is located at Electrolux's central headquarter in Stockholm. The Design Manager reports to the Market Manager of the White Goods Division, the single largest division at Electrolux.

The design of white goods is very closely related to their manufacture. Production technology sets the parameters for the forms that, for example, a refrigerator can take. Physical features are added to a given technical capacity to create differences between models and brands in the product family.

Design units add aesthetic features such as door handles, colors, interiors of refrigerators, etc, to basic product units.

Other aspects of design at Electrolux are the functional aspects of the products and their improvement. A number of standards for architectural plans and product performance have a strong influence on product design. For example, the size of refrigerators is adapted to the Swedish construction standard for kitchens (Svensk Byggstandard). The Swedish Board of Consumer Policies (Konsumentverket) evaluates functional aspects of consumer products and, among other things, the energy consumption for refrigerators.

Another important factor in the product development process is to develop and modify products to increase productivity in their production. Large production series are essential to gain economies of scale at the manufacturing plants. As noted previously, major technical innovations regarding the basic mechanics and physics of refrigerators occurred fairly early in this century, and these innovations were basically refined until the 1980s (in terms of production efficiency and impact product design) for Electrolux (as well as most other manufacturers).

Main actors involved in the process of finding alternatives for CFCs

The industrial actors involved in the replacement of CFCs in refrigerators, in the case of their use in refrigeration, are from the refrigeration-, compressor-, and chemical industries. The network we present, including the actors directly and indirectly involved, is mainly constructed from the perspective of Electrolux (as it is dominant in Sweden accounting for over 50% of market share) and is depicted in figure 5:6 below.

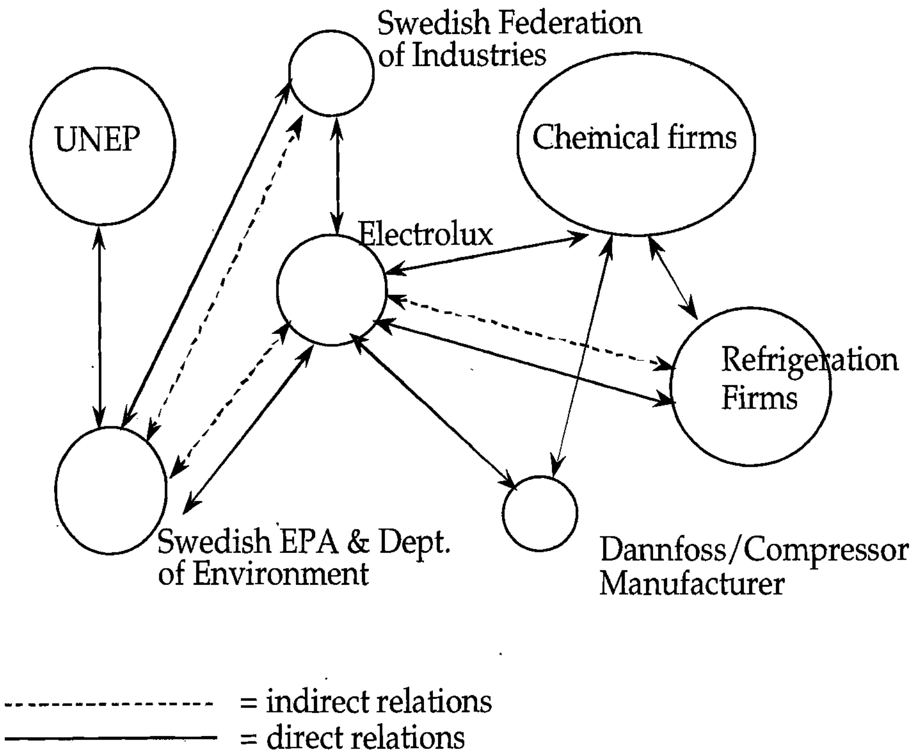

Figure 5:6: The Electrolux network in replacing CFCs

By the late 1980's, the global refrigerator industry was characterized by increased concentration in the three major market regions Japan, Europe, and the US (Sölvell, 1989). A few large multi-national firms dominated manufacturing, though the products were sold under many brand names. The world's largest manufacturer in the major appliance industry was Philips-Whirlpool. Some of the other large manufacturers included Electrolux, AEG, Bosch-Siemens, Mitsubishi, Matsushita, Hitachi, and General Electric. As markets matured, the familiar pattern of low-cost production, augmented by product differentiation (mainly by adding features to basic models) became key strategies. Refrigerators were manufactured in plants with highly specialized and automated assembly lines, with most components and materials sourced externally.

The German manufacturers AEG and Bosch-Siemens are today (and for some time have been) considered within the industry to be leaders in environmental product- and market development. However, in the case of CFCs the refrigeration industry was not prepared for the coming legislation, and Swedish legislation came into effect earlier than other countries forcing Electrolux to take an early initiative compared to other European competitors.

A few of the firms control worldwide supply of compressors. General Electric in the U.S.; Matsushita, Sharp, Mitsubishi, and Sanyo in Japan; and finally Dannfoss, Necci, Aspera (Whirlpool), Zanuzzi and Unidad Hermetica (Electrolux), in Europe. The Danish firm Dannfoss is a critical supplier of compressors to most European manufacturers of refrigerators. Originally, Dannfoss manufactured the Tecumseh compressor, developed in the U.S.A., under license. Due to the large size of the American compressors Dannfoss developed a smaller size for European needs, starting 1956. Since then, it has been among the leading firms in technological development of hermetic compressors for domestic refrigerators and freezers.

The compressor and the refrigerant are interdependent. Consequently, Dannfoss developed new compressors in close collaboration with some of their important customers (the refrigerator manufacturers) and a few chemical firms.

As noted earlier, in 1986 a small number (10-15) of large multi-national chemical producers accounted for the major part of the world production of CFCs (1.2 million tons in that year). Sweden had many CFC users. Two usage areas of CFCs, as a refrigerant and an active ingredient in the production of insulation foams, accounted for approximately 50% of Sweden's total CFC use. By 1987, the largest of the CFC producers were collaborating on research projects aimed at developing and testing substitutes for CFCs. The chemical firms also co-operated closely with the user industries to find and adjust suitable compounds that could replace CFCs in various applications. Chemical companies manufacturing plastics for the inner mantle of the refrigerator, lubricants for the compressor, and compounds for the insulation were also involved in the industrial network because of the potential for interaction between chemicals and compounds used in each of these refrigerator elements.

Today we (the market) demand that refrigerators should be energy saving, operating without any electric or other disturbance, and not be dangerous to the environment -- as well as achieving this at the lowest possible prices while offering a variety of sizes and other appealing physical design characteristics. CFCs are used as refrigerants and as blowing agents in the insulating (and structural) foam of the refrigerator. Available substitutes at the time of the study violated one or more of the "market demands" just mentioned. For example, HCFC-22 was not a very good insulator. This increased energy consumption, and the pipes and canals in the refrigerators were not adapted for HCFC-22 which would have forced investments in production facilities and new product form. This in turn increased both the size and the price of the product. All resulting from a simple change of a commodity product (CFCs) used in entirely different aspects of refrigerator production (e.g., foams) and functioning (e.g., the refrigerant medium).

Independent of the problems involved in finding alternatives to CFCs, everybody involved in the production or use of CFCs was investing large sums on the finding, testing, and evaluation of viable alternative compounds. Three Japanese companies, Daikin Industries, Showa Danko, and Asahi Glass published a preliminary report in the beginning of the 1990s on safety confirmation tests on substitutes for CFC's. According to the report, the compounds HFC 134a, HCFC 124 and -141b were observed not to cause any acute toxicity, sub-acute toxicity, irritability, or deformation, nor were they expected to have any carcinogenic properties.

Electrolux, (the largest CFC user in Sweden) was involved in Swedish regulation proposals both indirectly, through its trade organization, and directly through submitting its views to the legislative body, before the Swedish proposal was adopted. Top management from Electrolux also met with representatives from the legislative authorities during the process. Electrolux and its trade organization, Swedish Federation of Industries (SFI), were against a specific national regulation that did not harmonize with European Community or UNEP regulations. Instead Electrolux, in their comment to the Swedish Government Proposition 1987/88:85, agreed with the line proposed by the SFI, arguing for a voluntary program for the reduction of CFCs.

The proposition to gradually reduce the use of CFCs, with a total ban from January 1995, was adopted by the Swedish Parliament in May 1988. The refrigerator industry was given through 1994 to find a substitute for CFCs.

The CFC-project at Electrolux

In 1988, after the Swedish proposition to ban CFCs was in effect, Electrolux called a meeting where it was decided to start a CFC-project aimed at testing, evaluating, and implementing substitutes. Tests with various compounds for insulation, including water-based foams, were done by Research & Innovation at the Electrolux headquarters in Stockholm. At the same time, Dannfoss in Denmark tested different compressor refrigerants in co-operation with a few chemical firms. After a few initial tests, the Product Area Board, PAB, at Electrolux decided to work along the two main lines of (a) reduction and (b) replacement of CFCs by HCFC-123 and HFC-134a. PAB made strategic decisions regarding the products and production, setting the framework for further work at the different divisions. Beside staff members from Electrolux Major Appliances, division managers and representatives attending the meeting were members of PAB and making the decisions on the CFC-project were the Major Appliance subsidiary, Product Division Refrigeration (including its market department Marketing Europe), and Research & Innovation.

During phase one, Electrolux's aim was to reduce the amount of CFC-11 used in the insulation by 50%. The reduction of the compound could be completed in the spring of 1989 without reducing the insulation properties too much, thus, not causing energy consumption to increase. The first set of refrigerators produced with the reduced amount of CFCs started in January 1989 at the Mariestad facility, and was completely introduced by April the same year. By the end of 1989, most of the large refrigerator firms had halved the use of CFCs in the insulation foam. Parallel to the reduction project, several alternative substitutes were tested and evaluated at the Electrolux R&I department in Stockholm. R&I was working together with Hoecht and ICI on a few HCFCs as an alternative to CFC-11 for use in insulation foam. A decision was made internally during the fall of 1989 to concentrate further efforts to HCFC-123, which were publicly announced in February 1990. Among the reasons that were given, the insulation properties and price were considered the most important.

In the process of testing HCFC-123 problems regarding the fit to the plastic material used in the inner mantle of the refrigerator were discovered. To solve these problems, R&I worked together with the chemical companies ICI, Dow, and Bayer. New polyol-materials were tested in Stockholm together with foaming tests at the Mariestad plant. The insulation foam was evaluated for (a) how well it filled the space between the inner- and outer mantle; (b) its ability to attach to the materials; and (c) its insulation capacity.

A remaining problem was HCFC-123's relatively low ability to attach to the plastic of the inner mantle. Several of the chemical firms joined forces to find solutions to this problem as, for example, the co-operation between ICI and Montedison. The problem was not solved within the group of established relations to the chemical firms Electrolux had. In 1986 Electrolux acquired Zanussi, the leading major appliance firm in Italy. Through Zanussi's network of relationships, Electrolux came in contact with Montedip, a subsidiary to the industrial conglomerate Montedison. Montedip found a solution to the problem by inventing a technique to "nap" the surface of the plastic and by using materials that could be recycled.

Regarding the replacement of CFC-12 as a refrigerant, the initial screening and tests were mainly done by the compressor firms. Electrolux did not manufacture compressors up until the acquisition of Zanussi, who owned the ZEM-plant. Thus, Electrolux again used Zanussi's network and was working with ZEM but also with its major supplier, Dannfoss, to find alternatives to the CFC-12-based refrigerant. Dannfoss was Electrolux's strategically most important supplier of compressors, but ZEM and

Matsushita also delivered compressors to the Mariestad plant. Around 1/3 of the compressors were sourced internally from ZEM.

Initially Electrolux was working on two alternatives as a refrigerant: HCFC-22 and HFC-134a. The major problem was the compounds' compatibility with the lubricant used in the compressor. ZEM was testing different lubricants during 1989, and eventually found an ester oil that seemed to be functional with HFC-134a. Co-operative research projects to find alternative refrigerants were also conducted between universities and the refrigerator manufacturers. In Germany, for example, Bosh-Siemens, Electrolux, AEG, and a few other German refrigerator manufacturers jointly funded a research project at a technical university aimed at finding CFC substitutes.

In May 1990, the first refrigerator was manufactured using both HFC-134a as a refrigerant and HCFC-123 as an ingredient in the insulation-foam. The first 400 manufactured "CFC-free" refrigerators were delivered in November 1990 to a newly constructed apartment complex in Stockholm. During 1991, regular deliveries of the refrigerators were planned to start on a small basis. The main restrictions for a complete switch to the "CFC-free" refrigerator, were the limited supply of HCFCs and HFCs. All major competitors in the refrigeration industry had started projects in 1990 using the same type of replacements for CFCs as Electrolux.

On June 24, 1991 the consortium of CFC manufacturers testing HCFC-123, announced that tests had shown the compound to be potentially toxic, since male rats had developed benign tumours. Electrolux decided that the manufacturing and delivery of the award-winning refrigerators at the Mariestad plant should be postponed until the uncertainty regarding HCFC-123 toxicity was solved, or until new alternatives had been properly tested and implemented. In November 1991 the R&D department had tested HCFC-22 and HFC-134a as potential blowing agents for insulation foam. Due to the new facts the R&D and R&I departments projected it difficult to completely replace CFCs by the end of 1994.

The compressor manufacturers and chemical firms worked on solving some of the problems involved in using HFC-134a as a blowing agent for insulation foam. They made progress in developing a durable synthetic foam with the same insulation properties as HCFC-123, i.e., keeping energy use at the same or lower levels. Due to the progress made, Electrolux could (again) start the manufacturing of the CFC-free refrigerator. In the beginning of 1993 full scale production of CFC-free refrigerators and freezers started.

The preceding development of the "CFC-free" refrigerator involved several phases of which some were intimately connected to other industrial actors and their perceptions of suitable solutions to the CFC-replacement. The product development process at Electrolux went through four phases between 1988 and 1993, before the completed "CFC-free" refrigerator was put into full-scale production. Initially, the research laboratory constructed and tested prototypes. The next phase included product tests performed at the plant through a test-series of 20-30 refrigerators. Evaluations and changes were made continuously during this phase, involving both the compressor manufacturers ZEM and Dannfoss, as well as the chemical firms. The third phase was the production test, controlling if the product could be manufactured on the automated production-line. The last phase was the start of full scale production in early 1993.

Main events in the search for alternatives to CFC

The network that emerged around the events that forced the regulation of CFCs and around Electrolux, when different activities were initiated to solve the problem of replacing CFCs, was a function of historical technological and relational factors as well as of interrelated events and activities that took place in the course of change (see figure 5:7 below).

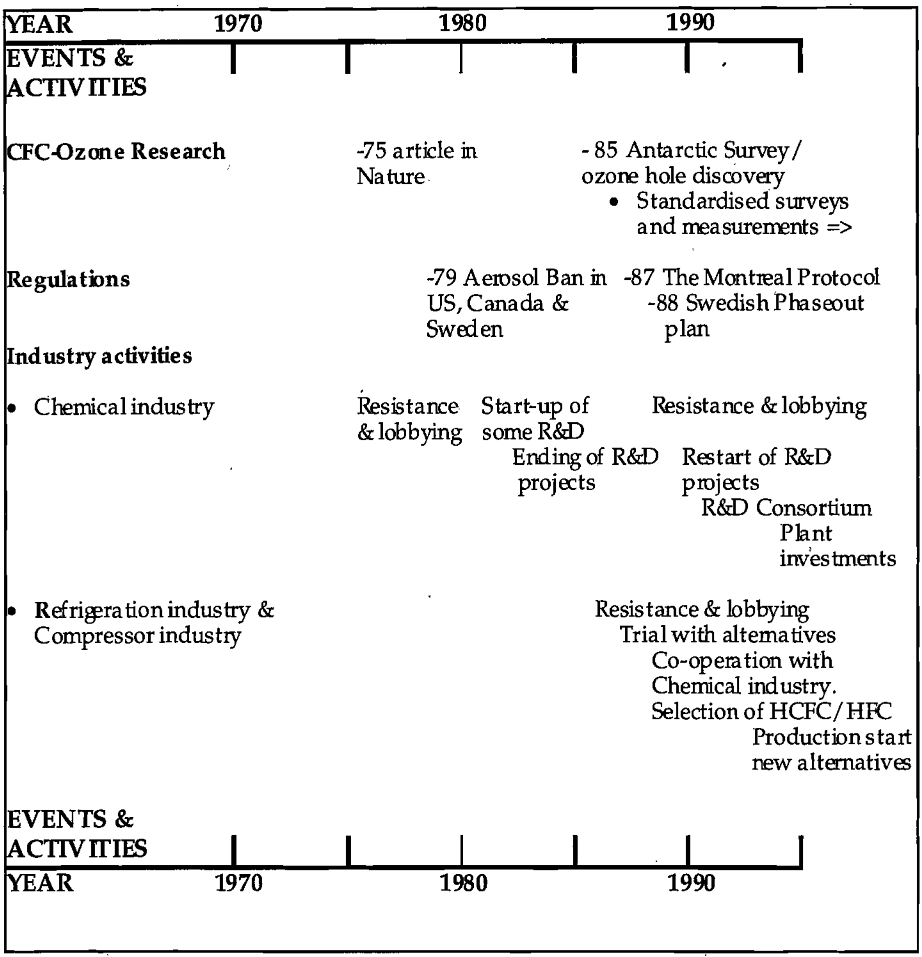

Figure 5:7: Critical Events and Industry Activities to replace CFCs in Refrigeration

CFC as a solvent in the electronic industry - re-defining the problem

The electronic industry in Sweden consisted at the time of the study of approximately 320 firms manufacturing a diversity of electronic products. The industry was heterogeneous and most of the firms small -- with less than 50 employees. Only 14% had more than 500 employees including, for example, Ericsson and ABB. The electronic industry reacted strongly against the Swedish proposition in 1987. Some of the larger users and their trade organizations were of the opinion that the timetable was too short to find alternatives, and that an earlier ban in Sweden could force the industry to make premature investments that could later lead to weakened competitiveness.

The Replacement of CFCs - Co-ordination on the network level

Electronic products have spread into an almost infinite number of applications. Approximately 90% of all electronic products manufactured in Sweden are for military, telecommunication and industrial electronic purposes placing high demands on reliability. The reliability of electronic products is to a varying degree dependent on the cleanliness of the components and circuit boards. Electronic components are sensitive to contamination both during the assembling process as well as during usage. The contamination of the boards and electronic components during the assembly phase is managed by using different cleaning techniques, while contamination from usage can be avoided to an extent by using different shielding methods.

Increased demand for smaller, lighter, and more reliable products was seen during the last decade. The trend toward smaller electronic units led to a switch-over to new assembling and soldering techniques. Hole assembly was earlier the dominating technique used in the industry but in the late 1980s was increasingly replaced by surface assembly in response to the demand for smaller units. Circuit boards assembled with the old technique were relatively robust and easy to clean. But changed manufacturing techniques and smaller components placed greater demand on cleanliness and reliability, and also increased the difficulty and complexity of cleaning.

The ban on the use of CFCs for cleaning purposes came into effect January 1, 1991. The CFCs used in the electronic industry were almost without exception CFC-113 as a cleaning and degreasing solvent for components. It gained popularity because of its non-flammable properties, quick drying time, and its relatively small impact on components and workers. During the peak year 1986, the industry was using about 400 ton/year of CFC-113. The electronic industry was also using a few other organic cleaning solvents.

These were: 1) trichloroethane; 2) prechloroethane; 3) alcohol; and 4) terpene. Cleaning solvents were usually used together with specialized equipment developed for specific solvents.

Some product areas had restrictions regarding type of cleaning method as well the type of flux that could be used. Commonly used in the industry was the American military standard, MIL, a publication prescribing methods, chemicals, and technologies to use in the manufacturing of electronic products. For example, one of the MIL standards did not allow water dissolvable flux for the manufacturing of military electronics. The MIL standard had been adopted in most every product application including civil usage.

<u>The TRE-project</u>

IVF, The Swedish Institute of Production Engineering Research, is an independent institute conducting applied research in the production engineering field. The department for material analysis at IVF helps firms, on assignment, to solve problems related to materials. The tasks can include laboratory analysis, literature research, and/or technical advice. In February/March 1987, IVF invited the electronic industry in the Nordic countries to a meeting regarding ideas for CFC replacements. Three different aspects were discussed in relation to the use and replacement of CFCs: a) production-line (production technology); b) the effects on the product; and c) usage-environment.

The issue first discussed related to the amount of allowed emissions of chlorine. The industry was concerned with product quality if CFCs were banned. In electronic products measures of migration, corrosion and cracks are important factors in deciding on a product's quality and potential lifetime and CFCs were considered to be well suited for the purpose of cleaning without causing such harm.

As a result of the meeting, IVF, a number of firms, Swedish EPA, the Nordic Industrial Foundation, and the electronic trade organization (Mekanforbundet) decided to set aside funds, SEK 18 Million, for the TRE-project (Technology for a Clean Environment). About 20 subscribing firms participated and industry federations as well as Environmental Protection Agencies from all Nordic countries co-operated as partners in the project. The project was funded 50-50 between industry and governmental institutions.

The project was divided into three phases, the first one starting 1988 and the third ending December 1992. The aim was to co-ordinate the resources in the Nordic countries in order to identify and test different alternatives for CFCs in response to the phase-out of the use of CFCs for cleaning purposes. The project was mainly intended for small and medium sized firms in the electronic industry, but some of the larger ones also joined. For example IVF gained access to Ericsson's research results evaluating alternatives. It was also decided that no chemical suppliers of solvents or manufacturers of cleansing equipment could participate in the project although firms outside the project co-operated with suppliers to test alternatives.

The purposes of the project were to: a) develop technology aimed at soldering without the use of CFC or, for several categories of products, without any cleaning at all; b) develop specifications of different grades of cleanliness for different applications; and c) develop methods for assessing cleanliness on cards and components for production processes.

Phase one - identification

The first step was to identify demands that the electronic industry had on its products in relation to CFCs. A survey of 80 electronic firms was conducted inquiring about the use of CFCs as a cleaning solvent. The survey also included general questions regarding demands on the products and the production-line. The popularity of CFCs was due to their properties. They evaporate quickly (= decreased drying time, i.e. the production process was running without any significant interruptions), and compared to other solvents are relatively harmless to humans and equipment.

As a result of the first study, cleanliness and reliability were identified as among the most important issues. The degree of required cleanliness varied, but the problem was common to all firms in the industry. Cleanliness could be critical, as in the case of precision mechanics where the main problem was to avoid stains and corrosion, while for others cleanliness was a matter of aesthetics. Also, many manufacturers were changing over to surface mounting assembling techniques using new soldering techniques as well as increasing the pattern density on the circuit boards. These changes intensified difficulties in cleaning electronic products. Most firms in the industry used the MIL standard as a guide to what cleaning methods and techniques to use in their operations.

The next step included testing a number of electronic components sampled from a selected number of firms in the industry. The aim was to determine the contamination levels of electronics manufactured at the time. Pre-studies were then performed to test and evaluate new manufacturing methods, solvents and solder chemicals in relation to the demands on cleanliness and reliability expressed by the industry. During the project the group of researchers at IVF received numerous calls from suppliers of solvents and cleaning equipment, who kept the TRE-group informed on the developments of new solvents, materials, and machinery made in the industry to replace CFC cleaning. HCFCs were decided against in an early stage since legislators indicated that HCFCs were not an acceptable long-term solution.

As a result of the studies, new standards for cleanliness and methods to measure cleanliness were developed. The results from the first phase were published in a report in the form of recommendations that were sent to the electronic industry[3]. The identified alternatives to CFC cleaning included alcohols, water, terpene, ultrasonic cleaning, CO_2-ice sputtering, and other cleansing chemicals. The project also identified methods of manufacturing that included no-cleaning in the combination of low solid flux and controlled process. The recommended method was based on the combination of application area, type of flux, type of soldering technique and demands on reliability. The results were also diffused in workshops held,

3 "Rekommendation från TRE-projektet rörande alternativ till CFC-användning som tvättvätska inom elektronikindustrin". IVF Report 1990-08-25. BB/TRE2.

for example, by the Norwegian EPA and resulted in a 50% reduction of the use of CFCs.

Phase two - testing and evaluating alternatives

The second phase included continuation of the work performed in the first phase aiming at a total phase-out of the use of CFCs for cleaning purposes. The first task was to verify the alternatives for CFCs identified earlier. The verification process included the development of specifications and verification of cleanliness for different solvents. The influence on the material and functioning of components resulting from the cleansing solvents and solder chemicals was also examined as well as testing different cleansing methods. Evaluation of the new alternatives was performed and, based on the evaluation process, measures for cleanliness developed.

Phase three - evaluation and diffusion of results

The technological results presented were: identification, verification and publication of alternatives to CFC-cleansing; evaluation of methods for cleanliness measuring; identification of mechanisms for corrosion, migration and cracking in soldering; evaluation of different solvents, soldering chemicals and cleansing methods. The results have been presented at numerous national and international conferences as well as resulting in some 20 articles in electronic industry journals. The results from the TRE-project were also included in a UNEP-report on alternative solvents replacing CFCs.

Industry Response

The electronic industry had different demands on their products and therefore adopted different methods in replacing CFCs. In 1993 50% of all firms chose a non-cleaning alternative. Among those who used a solvent for cleaning purposes the distribution was as follow:

45%	Alcohol
22%	Water soluble flux
13%	Water and saponifier
13%	Organic solvents
7%	Terpene

Source: Bill Brox, IVF

A few of the larger firms which also used international manufacturing facilities decided to stop using CFC-cleansing in all of their facilities, as well as banning input products or packaging manufactured with CFCs.

As a direct result of the project and its meetings, the participating parties have found a forum for exchanging information and experiences about advances in the electronics field. The actors participating in the project-group met five to six times per year and during the meetings a direct exchange of information and sharing of experiences between the participants took place. The project-group presented results and received information about the activities of the large non-participating firms through participating suppliers or contracted manufacturers. The TRE-project created an atmosphere of openness and security and information was exchanged freely and openly and as a natural outcome a forum for the Nordic electronic industry to meet and exchange experiences was created.

The replacement of CFCs in polyurethane production - industry coalition to comply

In June 1989 the Swedish Plastics Federation announced the joint decision of Cirrus AB and Nordflex AB, the two Swedish flexible polyurethane foam manufacturers, to stop the use of CFCs in the production of their foams by January 1, 1990. The industry thereby complied with the Swedish phase-out plan one year earlier than stipulated.

Polyurethanes[4]

Polyurethanes (PUR) are a group of plastic materials obtained through the chemical reaction of polyol and isocyanate compounds. PUR materials can be divided into three main product groups: (1) flexible foams; (2) semi-rigid foams; and (3) rigid foams. The largest application is flexible foams used for the manufacture of upholstered furniture and mattresses. Other large application areas include: flexible and semi-rigid foams used in automobiles

4 This section draws on Hirtz & Uhlig, 1985. Polyurethanes and their Market.

for cushioning and insulation purposes and in the production of integral skin products; rigid foams used as insulation in the construction of buildings and industrial plants and as insulation material in refrigerators, freezers and coolers.

The production of PUR is mainly concentrated on the three industrial regions, Western Europe, North America, and Japan. The market for PUR has undergone high growth since its start, with a production of around 45000 metric tons polyurethane materials in 1960 to the 1985 level which surpassed 4 800 000 tons (see figure 5:8 below for the nordic production). In Sweden the four industries: furniture and bedding, automotive, construction, and appliances play a dominant role in the polyurethane market, accounting for more than 2/3 of the total consumption.

Finland:		
	Espe Kauhava	1 000 tonnes
	Espe, Kouvola	3 000 tonnes
	"New company"	300 tonnes
	(SOK) Asko	1 400 tonnes
TOTAL:		5 700 tonnes
Sweden:		
	Cirrus	4 500tonnes
	Nordflex Gislaved	5 400 tonnes
	Nordflex Getinge	2 000 tonnes
TOTAL:		11 900 tonnes
Norway:		
	Brekke	1 300 tonnes
	Westnofa	1 200 tonnes
	Porolon	1 000 tonnes
	Ekornes Sykkylven	500 tonnes
	Ekornes Fettsund	3 000 tonnes
TOTAL:		7 000 tonnes
Denmark:		
	Cirrus Foltmar	3 000 tonnes
	Cirrus Metzeler	2 800 tonnes
	Danfoam	800 tonnes
	KBE	3000 tonnes
TOTAL:		9 600 tonnes

Figure 5:8: Production volume in the Nordic polyutheran foam industry 1986. **Source: SPF**

During the 1970s a transition from applications largely invisible to the end-user to highly visible usage areas took place. This shift caused a focus on the appearance and quality of the PUR surface which in turn opened up for the expansion into new markets. The fast expansion of PUR-materials into a multitude of applications induced the organization of PUR manufacturing and marketing into three specialized functions: (1) suppliers of raw materials who provide the chemical synthesis and compounds; (2) polyurethane processing machine manufacturers; and (3) the processors who use the chemical compounds to process and market foams, elastomers, and non-cellular materials that are used in the industrial production of end-user products. This early structuring of the industry still plays an important role in the organization of new product and market developments.

<u>The Flexible Foam Production Network</u>

In our study the main actors involved in the flexible foam production network were CFC manufacturers, polyol manufacturers, foam manufacturers and foam users.

The main suppliers of CFCs to Swedish flexible foam manufacturers were Du Pont, ICI, Hoecht, and Atochem. The firms that provided the chemical synthesis and compounds (polyol and isocyanate) to process the foam were also large international chemical firms. They had the technical expertise to find special solutions to various plastic applications. In some cases they manufactured all three main ingredients to the polyurethane foams: CFCs, polyols and icocyanates, but individual chemical firms more commonly bought the CFCs from CFC manufacturers and then used them to supply standard mixtures to the foam processing firms. Standards had been developed for different applications and qualities, but specialty compounds were sometimes developed to meet customer or quality needs. The number of compound suppliers to the flexible foam manufacturers in Sweden were around ten, the most important being Dow, Bayer, Shell, ICI and Union Carbide.

The flexible foam manufacturers were two relatively[5] large firms, Cirrus and Nordflex. They were selling foams in the Swedish market but also, to some extent, to the Nordic market. They manufactured cushioning and resilience products mainly for the furniture and automobile industry using both the slabstock and moulding methods (see below for explanation). In 1986 the total consumption of CFCs in the flexible foam industry was 500 tonnes, 9% of the total consumption of CFCs in Sweden.

The two large and important user industries were the car and furniture manufacturers. The buyers from the car industry consisted of the two Swedish firms Volvo and Saab. They were important to the flexible foam manufacturers in terms of putting forward demands on the flexible foam production systems (including product, logistics, quality aspects, etc). The furniture industry comprised several hundred small and medium size firms but also a few large and powerful ones, for example IKEA, KF, and the Kinnarp/Granstrand Group. IKEA was the single largest buyer of flexible foams in Sweden. IKEA bought mattresses directly from the foam manufacturers and other foam products indirectly, being the largest customer to many of the smaller furniture suppliers that in turn were customers to the foam manufacturers.

The Technical System of Flexible Foams

The production of flexible polyurethane foams takes place through an expansion process using polyol and isocyanate compounds and adding a blowing agent. The blowing agent could be gas or low-boiling compounds. The main agent for flexible foams is carbon dioxide (CO^2) which is received through a chemical reaction of water and isocyanate. Other agents include Pentane, CFCs, and methyl chloride. Flexible foam has an open cell-structure that causes the blowing agent to evaporate during or just after the production process.

[5] Large in terms of domestic production, but in comparison to the chemical firms they are very small. There were also 7-8 other manufacturers of foams that had considerably smaller production volumes (and had most often not foam production as their main business area) that have not been included in the study.

The most important quality dimensions of flexible PUR foams are: (a) density; (b) firmness; (c) static subsidence; (d) ability to circulate air; and (e) fire-safety. The manufacturing of flexible foams is generally done according to two methods; slab stock or moulding. The slab stock method casts the PUR into large blocks later cut into products, for example mattresses, whereas the moulding method refers to the process when products are directly formed into their final shape in the manufacturing process, for example armrests for automobiles.

CFC 11 was used in combination with CO^2 in the production of lower density foams (<25 Kilograms/Meter^3) being added in the polyol mixture in certain heavy quality foams to obtain a softer surface. In general, the primary quality of flexible foams is connected to its density and firmness. The higher the density of the foam, the higher the quality, which usually means a higher price. High density and firmness makes the foam more stable and increases its life-expectancy. The amount of water in the CO^2 mixture determines the density of the foam and the firmness depends on the polyol and isocyanate. Thus, adding CFC to the process made it possible to manufacture lower densities, since it served both as a coolant and a blowing agent, and made it possible to add comfort in making higher densities of foams softer. CFCs also served as a release agent contributing to the form and finish of the moulded product.

<u>Mobilization to handle the regulation threat</u>

The CFC-ban and industry mobilization through trade organizations

The Swedish phase-out plan banned the use of CFCs in flexible foams effective January 1, 1991. Prior to the 1988 Parliamentary decision to phase-out the total use of CFCs before the end of 1994, the flexible foam industry was partaking in lobbying activities as well as in government industry negotiations on time-tables for a potential phase-out. Much of the activities took place through the industry trade organizations. The flexible foam manufacturers worked primarily with the issue through The Swedish Plastic

Association[6] (SPF), but several industry organizations also co-operated on a jointly held view on the CFC issue. SPF co-ordinated its view with the Chemical Suppliers Association and the Federation of Swedish Industries.

Activities on the production level

When the CFC phase-out plan was decided, Cirrus and Nordflex considered the available alternatives. One alternative blowing agent, commonly used in the U.S., was methyl chloride. It is classified as a carcinogen and considered to be dangerous for both workers coming in contact with it and the natural environment.

"Myrsyra" was another chemical widely available that also was considered too hazardous for workers. An alternative to CFCs presented by the chemical suppliers was HCFC. Nordflex and Cirrus ruled out HCFC because it was not yet commercially produced and therefore only a limited supply was available. It was also considered too expensive as a blowing agent for lower densities of polyurethane foams. At the time, there were also signals from policy-makers and the Environmental Minister, Birgitta Dahl, that the use of HCFCs was not a long-term alternative to CFCs and that it would possibly be subject to future regulation.

<u>Co-ordinating activities through intra-industry co-operation</u>

In May 1987 the Federation of Swedish Industries and the Federation of Swedish Wholesalers submitted a letter to the Governmental Department of Environment and Energy giving a proposal for a phase-out of the CFC use. The industry did not object to the CFC phase-out stipulated by the Montreal Protocol, but objected to the proposed plans of an accelerated phase-out in Sweden. Later during the fall a number of discussions took place between representatives from the government and the industry federation where recognition of the environmental problems caused by CFCs was acknowledged and that a phase-out was necessary. Although the parties agreed on the types of CFC that should be considered in a phase-out, the timetable for a phase-out was still a subject of disagreement.

6 Sveriges Plastförbund

As a follow up to the discussions with the Department of Environment and Energy and to once again state the industry view on the CFC issue, in December the same year the Federation of Swedish Industries submitted a proposal[7] for a CFC phase-out. The proposal was based on the assumption that the industry must await international technology development to be able replace CFC. The proposal included specification of possible phase-out dates for specific application areas. Based on the timetable presented, and evaluations of potential reductions, the federation estimated a 25% reduction possible by 1991, in line with the Nordic Council's decision of 1987-10-07.

Cirrus and Nordflex are members of SPF. In the 1970s a special department[8] (hereinafter DFF - department for flexible foams) was founded within the SPF for firms which manufactured and/or processed flexible polyurethane. It started with the purposes of: (1) serving as a central institution for issues pertaining to flexible polyurethanes and their usage; (2) being an intermediary for contacts between the industry and governmental institutions; (3) working towards the implementation of common products and shared production standards as well as of norms for quality testing; and finally (4) being a forum for discussion and handling of technical and other issues of common interest to the department members. The board consisted of a yearly elected chairman, secretary, and a minimum of one additional board member.

In 1986 DFF was alerted to work with the CFC issue. A working group within the department was formed to follow political developments regarding a possible ban of CFCs. The working group at SPF discussed internally the problems with CFC-free production. The problems they discussed were related to the difficulties in producing lower density foams because of flammability, and to reach softness without CFCs in higher densities. The flexible foam manufacturers did not perceive other materials as a real threat to their products. Alternative materials for the same

7 "Avvecklingsprogram för CFC-användning". Promemoria 1987-12-22, pp 1-4. Federation of Swedish Industries.

8 Avdelningen för Flexibla Cellplaster

purposes were polyethers, horsehair, and paddings. They constituted a very small percentage of total use and were not considered as "real" competitive alternatives.

The pessimism that was first prevalent in the group turned after they had discussed the opportunities that could be gained by discontinued production of lower densities (i.e., lower qualities using CFCs as a blowing agent). Competitive developments in the furniture and mattress industry had led to a shift towards the use of lower density foams to cut cost and be price-competitive. The foam manufacturers saw an opportunity of stopping manufacturing the low density mattresses which they considered to be of poor quality, thereby solving some of the related quality problems.

In 1989 DFF agreed to stop the manufacture of foams with a density below 23 kg/m^3. A SPF decree, dated June 1989, was sent to all relevant parties informing about the voluntary agreement to stop the production of flexible foams with a lower density than 23 kg/m^3. They also agreed not to partake, directly or indirectly, in imports of CFC produced qualities. The agreement was effective from January 1, 1990, one year earlier than the Swedish ban stipulated.

<u>Finding a solution to the CFC replacement and beyond</u>

Competitive threats

After the agreement to stop using CFCs, DFF turned to a new problem. The flexible foam manufacturers felt a threat from the imported CFC-based products. The joint industry decision to ban the use of CFCs by not producing foams in qualities less than 23 $kilos/m^3$ resulted in customer demands for price compensations. The customers, mainly furniture manufacturers, argued that the 15% price difference between the qualities 20 and 23 $kilos/m^3$ should be reduced by lowering the price to the same level as for the CFC blown foams. Norwegian and Danish foam manufacturers also offered to deliver the lighter qualities made with the use of CFCs. Fruitless discussions for the purpose of reaching a voluntary import ban of CFC-based products had been held with the leading actor in the furniture industry, IKEA.

To fight this threat the industry again joined in trying to get an import ban. On an initiative from the manufacturers of flexible foams a meeting was held at the Swedish Environmental Protection Agency in October 1989. The purpose was to get an import ban on products containing CFC based foams. The industry representatives (from Nordflex and Cirrus) argued that the technical and market investments they had made to obtain an early phase-out of their use of CFCs, as well as the resultant environmental gains, were threatened from imports of the less expensive CFC-based foam products, especially from bordering countries.

The result of these attempts was an investigation of the amount of imported products containing CFCs or produced with the help of CFCs and a Swedish EPA proposal to incorporate import bans in the Swedish regulation SFS 1988:716. Such an import ban came into place effective January 1, 1991 after extensive negotiations primarily with representatives from the European Community.

Technical and social problems in response to the production halt

When manufacturing of lower densities came to a halt, the density 23 Kilos replaced the lower densities and was sold to fill the same purposes. The transition to the heavier foam increased the cost for the furniture industry but increased the quality of the foam. The foam manufacturers were positive since they did not have to sell foams for certain purposes that were earlier laden with quality problems. However the users were not emamoured and threatened to buy from other Nordic manufacturers unless they were compensated for the increase in price. Such price adjustments were agreed on.

After Cirrus stopped using CFCs in production, it manufactured the qualities 23-55 Kilograms/m^3 with an average density level of the foams of 27 Kilograms/m^3. Nordflex produced 36 different qualities of foam in the densities 23-55 Kilograms/m^3 and firmness levels of 50-330 Newton.

Before the agreement came into place, the flexible foam manufacturers were further pressed to find a solution to replacing CFCs from its largest customers in the car and furniture industries. In 1991 IKEA adopted the ISO[9] 9002 standards that stipulated a formalized quality system that is implemented to ensure a minimum standard/quality throughout the product system. IKEA, Volvo, and Saab were pushing for a general increased focus on quality aspects among Swedish suppliers, and put pressures on them to adopt such a system. A firm intending to be a supplier to IKEA, Volvo, or Saab had to join the ISO standard and go through testing and monitoring before becoming licensed by "Statens Provningsanstalt" and thereby qualify as a supplier.

Saab, Volvo and IKEA have demanded CFC-free production from their suppliers, through ISO-standards. IKEA had formalized its demands on suppliers to not supply products containing or produced with CFCs. Saab and Volvo have demanded CFC-free products since the end of 1989. There was no negotiation or discussion between the automobile and flexible foam manufacturers, the demand came as a decree from the automotive industry sent to all relevant suppliers.

Some of the technical problems that occurred after the ban were connected to the higher density foams. They had harder surfaces and were very heavy and more expensive for the end-user. With less flexible, heavier, and more expensive end products, Nordflex asked the parent company, Recticel, for help in solving the problems. However, it did not receive any support from Recticel during the first part of the CFC phase-out. Recticel was alerted during 1991 when the deadline of using CFCs in the larger European markets was coming closer and when Nordflex competitor Cirrus had started finding solutions to the problems that had occurred. Polyurethane suppliers were working on finding alternatives or additives that solved the surface softness problem. They had a standard set of polyols and a number of tailored polyols that were used to get softer foams. Cirrus did not work closely with the suppliers but was presented with standard solutions. Some of the alternatives Cirrus worked on at that time included: a) mix of specialty polyols (softeners); b) experiments with more icocyanates; and c) to dress

9 Swedish standards following international equivalent and are comparable to BS for example,

the foam applications with different types of padding bought from other firms.

During 1991 Rectciel's central R&D laboratory, IDC, in Belgium, started to test new polyols for their ability to get high density foams softer. The new concept that was implemented in production in November 1991 was to add softeners and hereby reduce the amount of isocyanat and still attain high quality foam as if using CFCs. Nordflex had also worked since the beginning of 1992 on the quality aspects of the foam in terms of its tensile and tear strength. Tests did not exist prior to the CFC-ban, but the industry became aware of the lowered strength in some foam qualities since the banned use of CFCs. Nordflex laboratory at the Gislaved plant is today responsible for quality tests and controls while the central laboratory in Belgium develops and tests new chemical mixtures and foam qualities.

The case of replacing CFCs - three applications - three processes

In this chapter we have described three industrial applications of CFCs and the processes of change that took place as a result of the regulations of the CFC compound. The changes that took place within the refrigeration industrial network was most extensively described due to the greater complexities involved in adapting their industrial system to the demands of CFC-free products. The refrigeration case represents an insight in to industrial strategies regarding complex technological and organizational change processes. The electronics' and flexible foam cases show different change strategies, one focusing on the technological system and the other on the network dynamic and postitions. Taken together the three cases will give us an overview of industrial systems with similarities and differencies regarding structural and institutional properties as well as to processual changes and choosen strategies.

In the next part of the thesis an analysis of the CFC-case will be presented.

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the British Standard.

PART IV ANALYSIS & CONCLUDING REMARKS

In the fourth part we will first analyse the change processes resulting from the regulation of CFCs as described in chapter 5. Each application of CFCs will be analyzed separately and then the three processes will be compared in relation to common or general patterns as well as to differences.

In the concluding chapter 7 we will discuss how the insights from the CFC case can inform us on the subject of sustainable industrial practices. Can we expect certain strategic responses or behavior in relation to environmental problems, given a specific set of characteristics in an industrial network or in an industrial sector? What will the implications for understanding industrial change be? Are there any implications for industry strategy and public policy? We will also suggest a few topics for future research.

Chapter 6 Patterns and processes of change in the CFC-case

The analysis of the CFC applications will apply theory to observations. Each application will be analyzed with regard to the technological, relational and institutional patterns of change prevalent in each case. The technological and relational patterns will be analyzed over time as well as the institutional processes that characterized the phase-out processes. The degrees of technological interdependencies, relational couplings in the network and degree of isomorphism of the solutions to the CFC challenge will then be used to analyze the relative inertia of each CFC application network.

CFCs' beginning and end: the case of Refrigeration

The application area that received greatest attention in Sweden and was given the longest phase-out period was the CFC-application in refrigerators. This should not be surprising considering the long period of use of CFCs in refrigeration, and bearing in mind that CFCs were invented to propel the growth of the domestic refrigeration market. The compressor refrigerator, first introduced in the 1930s, had been selected in 1987 as the worldwide standard. With demand for larger units in the household, the absorption technology introduced by Electrolux became inefficient and an industry-wide adoption of the compressor technology was seen in the early 1960s. The development of "a standard refrigerator" went together with the formalization of construction standards for multi-family homes, particularly in Sweden. Multi-family home construction programs were launched in the 1960s and 1970s in response to growing urban populations at a time of housing shortages in the cities. The goals of these programs included a general effort to continue to raise living standards for the majority of the population. These aims often became articulated in design forms like built-in kitchen appliances and the inclusion of refrigeration units in the homes.

Over the 60+ years since the introduction of CFCs as a refrigerant, many technological modifications have been made to the system of refrigeration. These combined changes resulted in CFCs becoming an integral part of refrigerators and their production, inter-locked with other technologies in the product and production systems. The technological interdependencies and inter-organizational couplings (particularly associated with product contents and production processes) will be the basis for analyzing the change processes that took place in the area of replacing CFCs in refrigeration.

Since Swedish industrial actors were the first to face CFC phase-out, Electrolux's work on replacing CFCs had implications for others involved in refrigeration, manufacturers who later faced the same demands to phase-out the use of the relatively simple chemical compound.

<u>The production system in the case of refrigeration</u>

The industrial system involved in the production, sales and usage of refrigerators involves a number of important resources. The knowledge as to how to build, the capital to finance manufacturing plants and processes, the connections to actors in the supply and distribution chains with supporting and complementary technologies, the services and expertise, these are some of a manufacturer's more important resources. The production system for refrigerators could be described as including two technological but related systems, the production-line and the product, each with its own logic and interconnected relationships and artifacts.

Being a capital intensive production system, great efforts have been made over time to increase production-line productivity. This particularly applied to Electrolux[1]. Since refrigerator production first started, their constant striving towards increased production efficiency achieved results. The refrigeration plants of today are large assembly plants with high degrees of automation. Outside firms mostly supply inputs to production and very few details are manufactured in-house. The basic refrigeration technology has not really changed since the early 1960s when the compressor motor became the dominant technology. Since then incremental changes have been made, mostly modifications to improve production efficiency or product design features. One of the more significant design changes, however, relates to the introduction of CFC blown foams as an insulation agent. This was significant because the replacement of fiberglass insulation by CFC blown foams influenced both the production process and the product design as will be shown below.

Production process and product component interdependencies

During the evolution of household refrigeration the production process system has been refined and increasingly more interconnected. As a result the design of a refrigerator has been strongly and concurrently related to the possibilities and limitations of the production line. All proposed product changes have been measured against their impact on the assembly process. If a suggested product change would cause large disruptions or modifications to the production line, its implementation was less likely to succeed.

Since the introduction of compressor technology in household refrigeration, CFC has been added at the end of the production line as a coolant in the radiator plumbing that connects to the compressor motor. The compressor motor has undergone some changes during its evolution. In the late 1950s a new line of compact compressors was introduced by some European manufacturers to meet the European market's need for refrigerators that were more compact. They replaced the larger North American "Techumseh" compressor that had dominated the market up until then. Since the introduction of the compact compressor no radical changes were

[1] Efforts to increase production efficiency are mentioned in almost every issue of Electrolux's annual report

made to the compressor system or it's components prior to the Montreal Protocol.

One major design change that did indeed occur (prior to the regulation of CFCs) was the introduction of foam as insulation material in refrigerators in the late 1960s/early 1970s. This change proved to be fundamental to both product and production processes. Prior to foam, insulation consisted of fiberglass or other materials also used in other standard applications, for example as insulation in buildings.

The construction of the refrigerator and the installation of fiberglass insulation were neither integral nor highly related. The fiberglass was added in the space between the inner and outer mantle of the refrigerator and did not affect the materials used in the mantles. Thus, apart from its insulating functions, insulation itself was not a critical, nor a highly integrated, component of the refrigerator prior to the use of CFC blown foams.

Foam insulation changed the design and production processes fundamentally as the insulation became part of the structural integrity of the refrigerator shell itself. The use of foam reduced the thickness of the walls and increased the insulation effect, thus energy efficiency was improved. CFC was "injected", together with other chemicals, into the space between the inner and outer mantle of the refrigerator. The mixture of chemicals created a foam that served two purposes: to stabilize the structure and to insulate from loss of cold. The materials of the refrigerator walls were also affected by the new insulation technology/chemicals, which increased the inter-relationship between the parts. This new technique of integrating the insulation with the inner and outer mantle was called "sandwich construction"[2] which led to an increased technological interdependence of the technology in the refrigerator.

Global oil-crisis creates institutional forces for change in product design

The "forces" present to implement such a change in design and production were indeed great and increased in the 1970s. They stemmed from strong

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since the early 1930s.

[2] Term used by the refrigerator manufacturers to describe the construction where the inner and outer walls of the refrigerator are "glued" together by the insulating foam in a 3 layer fashion.

demands on energy efficiency brought about by a truly global oil-crisis. That crisis mobilized consumer affairs, KoV,[3] to make product comparisons which created both coercive (consumer demand) and mimetic (company/product comparisons) isomorphic pressures to adopt energy efficient technology.

One such solution was to improve the insulation in the refrigerator. CFCs were already known and used as a coolant by the refrigeration industry while adoption of foams using CFC propellants to reduce energy use was relatively easy. The public debate in the mid- to late 1970s on the harm of CFCs as a propellant in aerosol packaging did not spill over to refrigeration and the refrigeration industry felt relatively unaffected by the regulatory pressures to ban CFCs at the time.

Also, the institutional forces that supported the use of CFCs in insulation were great. Strengthened norms regarding energy use and efficiency in society at large, paralleled with institutional measures brought forward by institutions like KoV, helped to support the refrigeration industry in the transition to the new foam insulation technology. Energy efficiency became the strongest norm, guiding product development and design in the field of refrigeration. Today there are numerous product reports and tests available to the consumer with energy consumption comparisons. Tests are performed not only by KoV, but also by retailers and consumer associations. The manufacturers also provide detailed product information with regard to the energy use and efficiency of their products.

Thus, since the 1970s energy consumption has been increasingly institutionalized. It has instigated product improvements as well as shaped the design of the refrigerator and its production system. Also, energy consumption is one of the most communicated elements in marketing communication as well as consumer reports, that over time have shaped consumer preferences and demands on a refrigerator. Today it is virtually impossible to buy a refrigerator without learning about its energy use.

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[3] In Sweden Konsumentverket, KoV, (Consumer Affairs) was instrumental in influencing the direction of refrigeration design by strongly emphasizing energy efficiency as a major performance criteria. KoV regularly tests and compares products. Usually the test is paid for by the producer.

The "perfect" refrigerator production system - before the discovery of the ozone hole

The production system for household refrigerators was at the time of the Montreal Protocol negotiations characterized by perhaps even greater stability than in the 1970s. The dominant product design was compressor technology, using CFC as a coolant, and CFC propelled insulating foams to which fundamental product structural adaptations had been made. The walls of the refrigerator had become thinner due to the efficiency of CFCs and the interior had adapted accordingly with increased shelf-space. The assembly line was adapted and optimized for the production of this technology, as the technology itself survived the previous "crisis in design" brought on by the oil crisis.

By this time mimetic pressures were increasingly evident. Virtually no differences regarding functional (especially energy use and basic performance in the home) criteria could be found between brands. Critical input resources used for production were the same. Differences that could be seen were primarily attributable to visual design features. In relation to CFCs the production system with the product and production resources could be characterized as a highly interdependent system with exceedingly interconnected technological artifacts (figure 6:1). The production line was largely automated and dependent on a well functioning flow of inputs along the factory line. The productivity of the plant was sensitive to disruptions along the production line. Disturbances were costly and measures to protect against such disturbances were part of the design of the production system. Any new product development was evaluated with regard to existing production technology and possible disruptions of the assembly line. The CFCs were added at two different stations along the production line, which increased the complexity in replacing CFCs.

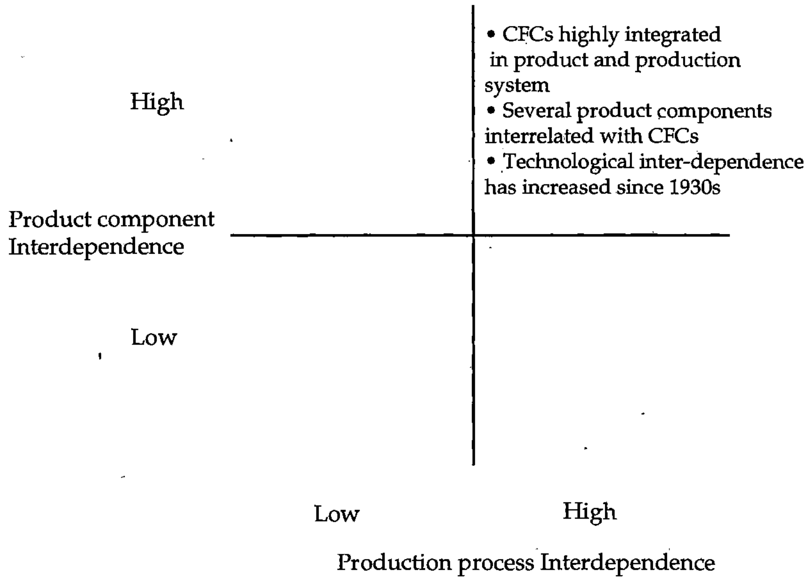

Figure 6:1: Technological interdependence in the refrigeration production system 1986

The refrigerator in itself was also a system of technological parts. The design of the refrigerator was highly interconnected with the possibilities of the production line. The basic design features of the refrigerator had been shaped and adapted to each other since the 1930s and the production line had been set up accordingly. Over time changes in the refrigerator design had been increasingly dependent on existing production technology and design and we can characterize the technological system of the refrigerator as highly interdependent. The use of compressor technology was inter-related to the coolant, which in turn was related to the materials in the pipes and to lubricants used in the motor.

Thus, by the mid- 1980s the refrigeration production system was highly interdependent with regard to its technology in product and production. The high technological interdependence had been created over time through path-dependent processes.

<u>The relational system and processes</u>

The actors in the refrigeration industrial system were few and highly internationalized. Main actors in the refrigeration industrial system were refrigeration firms, chemical suppliers and compressor firms. The network of supplier relationships was highly overlapping between competing refrigeration firms and characterized by stability and standardization. In Europe the supplier network for many of the critical inputs was virtually the same for all refrigeration manufacturers. Compressor technology suppliers were few and in principle product development was only carried out by one actor in Europe, Dannfoss, while the other suppliers of compressors were often manufacturers owned by the refrigeration firms to secure a second sourcing in relationship to Dannfoss. In Electrolux's case, it had used the same supplier, Dannfoss, since the purchase of Elektro-Helios and its compressor technology in the early 1960s. With the acquisition of the Italian white goods manufacturer Zanussi, a smaller compressor manufacturer was included and added as a supplemental and price competing supplier. Thus, the relational system in refrigeration was characterized as a tightly coupled system with stable and routinized relationships.

Chemical suppliers were large and international firms, also few in number. For the most part, CFCs were supplied to most refrigerator manufacturers by one or two suppliers. The relationships in the supplier networks at the time of the Montreal Protocol were characterized by high stability. Both distributive and administrative routines were well established. The main chemical suppliers delivered not only the CFCs but also a mix of chemicals to be used in the foaming process as well as the chemicals for use in the making of inner mantles of the refrigerator. The metal and plastic used in a refrigerator's outer and inner mantle react with the chemicals used in the foam and a change of chemical supplies might cause defoamation of the refrigerator with consequent interruption of the production process. As well, the different chemicals used in the foam itself had to be compatible, giving tested chemicals clear advantages over others, while the cost of changing one kind of chemical for another could be considerable if it resulted in an interruption of production.

Accordingly, a stable relational system could be observed, with high coupling between the industrial actors. Thus, in line with the theoretical framework, the industrial system in the refrigeration industry could be characterized as tightly coupled and highly interdependent, see figure 6:2.

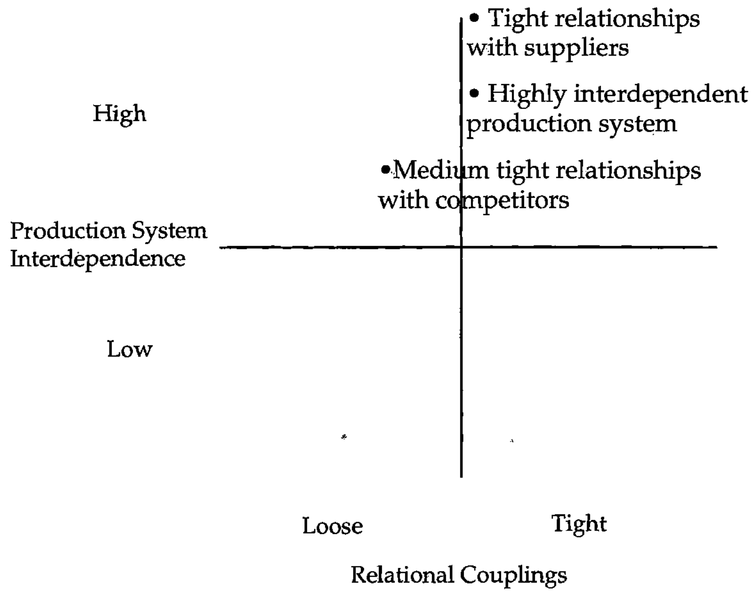

Figure 6:2: Interdependence and couplings in the refrigeration industrial network 1986

Institutional system and Isomorphic processes in the refrigeration industry

The industrial system involved in the manufacturing of household refrigerators has evolved over a 70 years period. Not only have the technology and the actors developed and adapted to each other, the development has also been supported by the evolution of institutional rules, norms and systems to support the manufacturing and use of refrigerators.

On the user side, infra-structural investments in society, such as electrification, have been crucial for the development of a mass market. Safety rules regarding use of refrigerants have also influenced development towards the use of compressor refrigerators. CFCs were specifically designed to reduce risks of flammability and explosions when first developed as an alternative refrigerant.

The development and design of household refrigeration was also supported by other societal projects such as architecture and building ideals and standards. Functionalistic ideas and architecture influenced the interior design of kitchens to incorporate built-in appliances which in turn influenced the design of refrigerators. As mentioned, the development of product standards in Sweden as well as efficiency in production was spurred by large municipal building projects for multiple homes between 1940-1970s. A few large builders came to be important in shaping the demands on the design and function of the refrigerator and price became an important competitive tool. Thus, the refrigerator industry, experiencing increasing pressure to improve production efficiencies, became more professional and specialized.

Further, events like the oil crisis, technological possibilities, and the professionalization of refrigerator manufacturing induced a higher degree of institutionalization of the refrigerator industrial network. Energy efficiency and safety were influential in shaping functional demands on the refrigerator, which in turn pressured the design of the product and production processes to adapt to existing systems. The developments since the oil-crisis show an increase in couplings and interdependencies. The number of actors in refrigeration has been drastically reduced to a few large firms operating in an international arena. The emphasis on energy efficiency has also institutionalized norms which has increased product standards - and thus spurred tighter couplings and higher interdependencies.

To summarize, the industrial system in refrigeration was at the time of the CFC regulations in 1986 characterized by a high degree of technological interdependencies with many standard technologies with high mutual interdependencies. It was also characterized by the dominance of a few large industrial actors who where connected in a tightly coupled relational system. In many instances European refrigerator manufacturers shared the same supplier network, or at least had highly overlapping networks. The relationships to main suppliers had been stable and were rarely discontinued. When new relations where developed it was usually as a result of mergers, or to secure second sourcing. The refrigeration industrial system was also highly institutionalized due to both specialization and professionalization of the refrigerator industrial system as well as to demands on greater safety and energy efficiency that were translated into product design. In accordance with the theoretical model we can describe the refrigeration industrial system as having a high degree of interdependence in the technological system with a few large actors in a tightly structured industrial network (see figure 6:2).

CFCs and change processes in the refrigeration network

The actors in the industrial network in this case have coordinated their resources and activities to solve the replacement of CFCs in refrigerators. Personnel from R&D departments, product and production engineers, and managers from refrigerator, chemical, and supplying companies actively participated and combined experiences and resources in the process. Individual actors in the involved industries also built relationships with legislative bodies in developing and negotiating solutions to the CFC-problem.

The coordination of resources and activities in the industrial network can be viewed as a formation of an informal, cooperative attempt to resolve the CFC replacement issue. Reasons for cooperation (as compared to individual, isolated activities) that can be identified were: (a) to reduce lengthy development and testing procedures, thus increasing the speed of the process as well as reducing costs; (b) gaining access to other actors' resources, both knowledge and capital-based; (c) reduction of overlapping activities; (d) for chemical companies to maintain their position as suppliers of coolant and insulation compounds to the refrigeration firms; and (e) to legitimize the chosen solution by presenting a unified result.

The cooperation formed in this case was an extension of earlier exchange relationships between the actors in the network. A tighter cooperation on research projects was implemented in order to test and adjust the new compounds to the refrigerator as well as in the production-line. The chemical manufacturers, being pressured to find CFCs substitutes, had to quickly test their suggested replacements for various applications. Some of the driving forces to find broadly accepted solutions were the availability of earlier developed compounds, uncertainties regarding differences between the CFCs and the substitutes, as well as the environmental status of the new chemicals.

Thus, engaging in collaborative network projects enhanced the diffusion and support of the chosen solution in the industrial network of users. The support in the industrial system also strengthened the industry position towards legislators, reducing the risk of regulatory action towards the new compounds. The existence of a tightly coupled network helped the actors to identify possible solutions relatively fast as well as to start test projects on alternatives. But the network also prevented new, perhaps more innovative, solutions from being developed.

A number of observed isomorphic pressures were propelling this process of uncertainty reduction. Coercive pressures stemmed from the international and national regulation of CFCs. The previously discussed alternatives to CFCs were included as suggested substitutes in the Governmental and UNEP documents. These suggested substitutes could be understood as standards for what solutions to adopt. Coercive forces could also be identified in terms of pressures felt from within the network to adopt a certain solution. The chemical industry had solutions that were developed as a response to the 1979 ban, which had never been tested for various applications, and were active in promoting these compounds.

The process of finding substitutes for CFCs was mainly performed within already established relations. The probable greater relative power of the chemical corporations in terms of their dominant position in the CFC market enabled them to steer the refrigerator and compressor firms towards HCFCs and HFCs as substitutes. The chemical firms had the knowledge and resources to engage in developing and evaluating different compounds that the other actors lacked or had no interest in pursuing. These established relations could be viewed as a force or persuasion towards an isomorphic solution, thus hindering the refrigerator firms from finding solutions outside the established relationships.

Once a solution became perceived as successful by leading firms, other refrigerator manufacturers applied the same solution. Thus, mimetic behavior was observed when the solution applied in one firm was adopted by others in the network through imitation. The mimetic pressure could be observed in both the chemical and refrigerator industry. The CFC manufacturers quickly adopted the solution proposed by some of the leading chemical firms like Du Pont and ICI. Cooperative research forces were soon organized, thus reinforcing the institutional processes towards an isomorphic solution. Collaboration to quickly find alternatives to CFCs was also supported by environmental policy-makers and other legislative bodies. A number of seminars, workshops, and other, less formal, arrangements supported the diffusion of HCFCs and HFCs.

One explanation for the fast adoption of this solution is that all the actors in the study belonged to large, international, and mature industries. In Weick's (1982) terms the relationships between the actors involved were all tightly structured and the established, highly structured network of relationships enabled the chemical firms to rapidly test the suggested substitutes for different applications in close cooperation with the refrigerator and compressor firms. In more fragmented industries the process would probably have been slower.

In this case, the tightly structured relationships which doubtless enhanced the speed of finding substitutes for CFCs, at the same time impeded new and possibly better solutions from being found outside the network. Thus, network relationships can be said to be have been both a blessing and a curse. A blessing because they facilitated the organization of actors and resources to solve common problems, but a curse in that they probably hindered the development and adoption of innovative solutions originating outside the established structure.

From the perspective of the firm, it would have been very expensive and risky for Electrolux to develop the chemical competence needed to find a better solution on its own. It lacked the necessary resources to develop a close substitute for CFCs and was not ready to develop a completely new technological solution to refrigeration and insulation. Electrolux also viewed it as far from certain that customers would be willing to pay significant premiums for "greener" refrigerators. Thus Electrolux did not perceive it feasible to develop its own solution. Instead, Electrolux participated in the institutionalization process of the industrywide environmental compliance, replacing CFCs first with HCFCs/HFCs and later with pentane, a volatile fluid paraffin hydrocarbon contianed in petroleum.

The stability in the refrigeration industrial network relationships, uncertainties regarding the alternatives, lack of incentives for competitive solutions, as well as readily available compounds offered by the chemical actors were likely reasons for the compliant behavior of the actors in the network involved. Significant attempts to find more environmentally apt solutions than these replacements were conspicuously lacking in this network. The observed network behavior is attributable to a combination of relatively high degrees of technological and relational lock-ins, (see Figure 6:2) and institutionalization processes in the network studied. We will compare this network on these dimensions in relation to the other network cases we examined. We consider this case to be a manifest example of when system effects produce macro-behavior different from, and often counter-intuitive to, the motives of participating members in the system (e.g. Schelling, 1979).

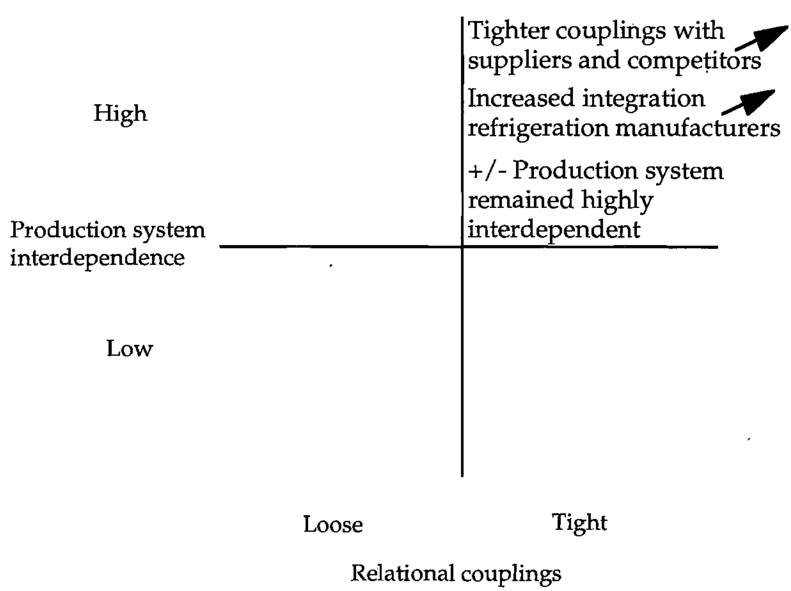

Figure 6:3: Changes in interdependence and couplings in the refrigeration industrial network 1986-1995

If we analyze the events during the 10-year period of the CFC phase-out we can see that the already tightly connected network of actors went through a structuration process where the relationships became even closer (compare figure 6:2 and 6:3). One such structuration outcome was an increase in the interaction between competing refrigeration firms. The relationships between competing firms developed into several cooperative projects such as the one between Electrolux and AEG at a German university to test the properties of CFC alternatives. AEG and Electrolux have since merged.

Cooperative efforts were formed not only between refrigeration firms but also between chemical manufacturers and between groups of actors in the whole supplier network. For example, in testing CFC alternatives refrigeration firms, CFC manufacturers, compressor firms, and plastics manufacturers were all involved in finding solutions to specific problems that evolved during the process.

Thus, the Montreal Protocol and the Swedish CFC regulation created an awareness of shared problems in the refrigeration industry that spurred increased interaction and exchange of knowledge and other resources. In light of the earlier Swedish regulation, Electrolux could have had the opportunity to gain an advantage relative to its competitors in launching the first "CFC-free" refrigerator, and thereby attempted to change its strategic position in the network. But instead the resources and actions of the refrigerator firms were coordinated, the structuration increased, and as a result the isomorphic pressures to adopt a common solution, no position changes between the refrigeration firms were apparent.

On the other hand, some positional changes could be seen on the supplier side. One supplier that came into the Electrolux network with the acquisition of Zanussi played an important role in solving a chemical compatibility problem during the phase of testing CFC alternatives and as a result received greater status in Electrolux's network of suppliers. But in general few new relationships developed, the existing supplier relationships being strengthened during this change process. The large CFC suppliers not only played an influential and active role in identifying and supplying the alternatives, but also strengthened their position vis-a-vis the refrigeration manufacturers.

Thus, stability in both the technological as well as the relational structure was maintained in the refrigeration network (see figure 6:4). Change in the production was minimal and in line with the technologies and techniques used before the CFC regulation. Due to structuration of coordinated efforts to find standard solutions at the network level, we can understand the result of this change process as a manifestation of the high interdependence in the production system and the tightly coupled relational system. The interdependence in the technological product and production process systems had gained momentum over 50+ years, manifested in technological lock-ins and resulting in a relatively high degree of social inertia.

The relational system that evolved around the technology was also highly structured with tight couplings, especially in the supplier network but also among specific professionals in the refrigeration industry. The engineers involved in the CFC change project(s) were often physicists with shared educational background who often met at trade fairs, conventions and professional meetings. During the CFC change process the interactions between them increased with exchange of information, knowledge building and cooperating in testing. This resulted in a tightening of the bonds between the people involved in the CFC change projects.

Conclusions from the Case of Refrigeration

In summary, we find that cooperative efforts and isomorphic pressures, emanating from within the established industrial network as well as from legislative bodies, helped to shape the solution of the CFC replacement. HCFCs and HFCs, the substitutes for CFCs proposed by the chemical manufacturers, were widely adopted among the major refrigerator firms. The solution became institutionalized through a process of coercive and mimetic pressures.

These firms were prisoners of the environmental dilemma and it is easy to view inter-organizational collaboration as a major solution (cf. Axelrod, 1984; Schelling, 1979). For example, Teece (1992) suggests that such collaboration can promote innovation through coupling complementary assets, users and suppliers, competitors, and technologies. He stresses that horizontal cooperation can contribute more to innovation than competitive diversity since the former assists the development of standards, motivates more R&D investments through higher pay-off expectations, and reduces wasteful duplication of effort.

Our case shows that cooperation on the network level may not always create sustainable solutions, but may institutionalize adoption of less ideal solutions. Interlocking relationships and technologies may force individual firms to adopt a certain solution already adopted and diffused in other parts of the network. This highlights how important it is to study industrial cooperative or collaborative efforts from a multi-level perspective, since our findings restrict the reasoning of Teece (1992) that horizontal cooperation promotes innovation. Benefits from cooperative efforts experienced by individual actors at the micro- and network levels may be negated when analyzing the consequences at the societal level. A rapid and un-problematic change procedure with the adoption of a specific solution diffused in an industry may hinder efforts to develop new cleaner technologies.

The development and diffusion of innovations are typically driven by expectations of future gains (e.g., Brown, 1981; Walton, 1987). The more uncertain and potentially lower these pay-offs are, the less likely firms will be to invest in R&D and adopt innovations, and the more likely that firms will resist mandated adoption. In this case, the production system interdependencies framing the problem and motives for developing more environmentally correct solutions were lacking. As long as environmental pressures are seen more as threats to be minimized than as opportunities to be individually or collectively exploited, the defensive side of inter-organizational cooperation can be expected to dominate.

It would indeed be remarkable if an industrial network with the vast resources at the disposal of most of the leading firms within it were not <u>able</u> to develop environmentally apt solutions, rather than the seemingly inapt HCFCs over the period of almost two decades since the first warning signals. We suggest that the phenomenon of adapting an isomorphic solution is related to uncertainty and processes at the production and relational system level. The technological cooperation and information sharing of the industrial network studied is far from sufficient to internalize the environmental externality of CFCs. To solve an environmental problem in interlocked network structures may not be enough to internalize environmentally apt solutions, but may in fact hinder such development. The system effects of inter-related industrial relationships and technologies may slow or hinder the development and adoption of radical new solutions and may also impede the diffusion of new environmentally adapted products or procedures. It will, however, expedite the diffusion of chosen solutions. In this case, the industry-wide adoption of the chosen environmental solution was made possible through the collective efforts of the network and the process of institutionalization. In fact, the process of solution selection was a key aspect of its diffusion and adoption among participating firms.

In the case of refrigerators, interlocked relational structure and technological path-dependencies played a major role in shaping the isomorphic CFC solution. Imitation and coercion regarding solutions shaped the solution while keeping the network structure and the production system relatively unchanged. A possible alternative outcome could have been the adoption of the already existing thermo-technology. This technology was evaluated at Electrolux in terms of its influence on the ozone layer and possible contribution to the greenhouse effect but was quickly abandoned due to the necessarily large investments required in the production system.

Breaking up from institutionalized norms - the case of Electronics

In the electronics case CFCs were used as a solvent for cleaning (and 10% degreasing) purposes. Concerning the application of CFCs in electronics, we have several conditions that are different from the refrigeration case. The use of CFCs in the electronic industry was limited to being a part of the production process and not an integral part of the product. Only one type of CFC was used, CFC 113, but with many users for a large variety of electronic products. Users numbered about 200, ranging from small regional to very large multinational firms. The highest consumption in Sweden was to be found in the instrument and precision mechanics industry, CFC 113 being used as a cleaning agent for electronic equipment where extremely high demands on cleanliness were present (The Nordic Council of Ministers; 1993). The network of suppliers relating to CFCs was smaller and tighter. CFC suppliers were few and consisted of very large international firms. The cleaning equipment/machinery used in the production process was supplied by two German firms.

<u>The Production System in the case of Electronics</u>

Figure 6:5 places the electronic network in our product/production interdependence framework. In the case of CFCs and Electronics the use of CFC was limited to the production process and only had implications for the functioning of the product (most often circuit boards). Cleaning and degreasing of the circuit board was done as a matter of standard practice and integrated in the production process. Some electronic products were military applications where formalized standards had developed that included detailed descriptions of washing techniques and approved solvents i.e. CFC 113.

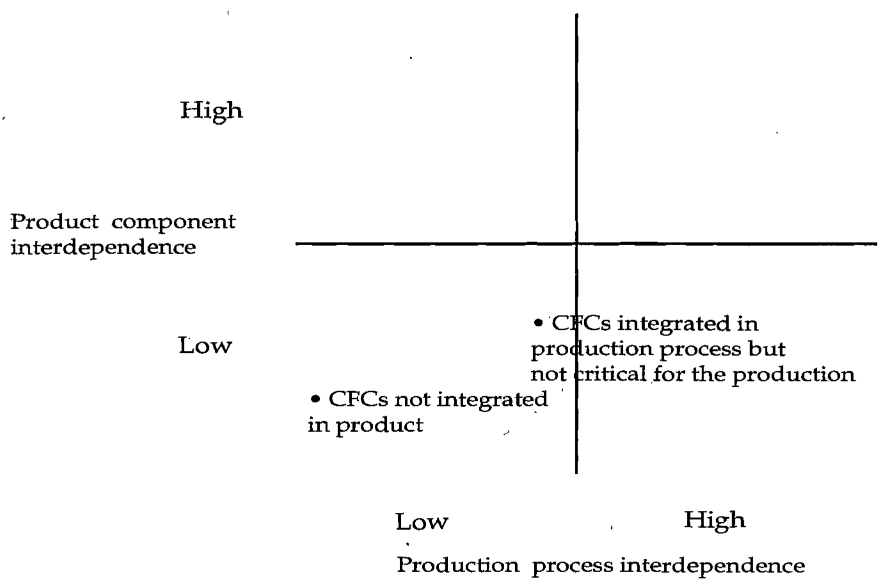

Figure 6:4: Technological interdependence in the electronics network 1986

The actor network could be described at several levels in this case. If we look at electronic manufacturers, we have many small, medium and large firms with little or no exchange on the horizontal plane. Thus, the electronic network in this sense could be described as very loosely coupled. On the other hand many of the small and medium sized firms were suppliers to larger manufacturers, for example to Volvo, Saab, and Ericsson. So if we include supplier and customer relationships we have individual examples of very tightly coupled relationships with great interdependencies. However, as the case unfolds, there were few coordinative attempts to address the CFC issue on the actor/relationship level. Also, early in the process, the TRE-project took a leading role in exploring the CFC-issue, thus the initiative, governance, and control was transferred from the industrial actors and the production level to a higher level of the network.

The TRE-project included electronic manufacturers in their project for advisory and test purposes, but the operative and management parts of the project were with the scientists at IVF. Therefore, we have chosen to classify the electronic manufacturers network as loosely coupled with low interdependence on the production system level.

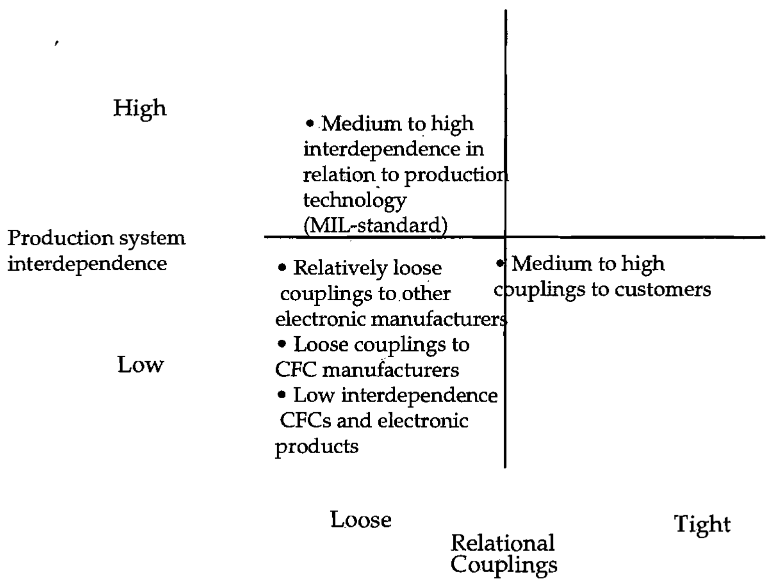

Figure 6:5: Interdependence and couplings in the electronics network 1986

Isomorphism in the case of Electronics

In the case of electronics, the fragmented nature of the network structure was probably the most influential variable in the establishment of an industry-supported project intended to influence the coordination and mobilization process in the network. The research organization in this case had an influential role in re-defining the problem for the network, which differed rather from the refrigeration and flexible foam cases. This involved re-defining the problem of "finding a solution to CFCs" into "why do we clean electronic products?". This re-definition acted as a major force in shaping the patterns of change as well as the outcome of the change. The environmental problem was transformed in this case into the need to revitalize the technology in the industry. It thereby resulted in the adoption of plurimorphic[4] solutions, i.e. several new "wash-free" mounting techniques were launched, some applications could use water based washing techniques, and for some of the product applications cleaning was identified as not being necessary at all.

In this case technological standards (i.e., MIL) could be seen as an institution shaping the perceptions of the technology and the elements in the production processes involved in the production of that technology. So in relation to the use of CFCs, the MIL standard was a taken-for-granted institution that was incorporated and referred to in contracts.

So before the regulation of CFCs, the electronics network can be said to have been on a fairly stable course with regard to the use of cleaning methods. The regulation and the forces working in the change process de-stabilized the system. Varied solutions tied to specific applications emerged as a result, i.e. plurimorphic solutions, and the production system interdependence decreased further.

In our framework, inertia resulting from structuration tendencies of the electronic network was not as great as in the refrigeration network. Relational couplings between actors were fewer (on the horizontal plane), and production system interdependence was quite low as methods/solutions for cleaning could be eliminated, entirely in some cases (See figure 6:6).

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[4] Plurimorphic is used here as opposed to isomorphic to account for multiple solutions. Pluri is defined as "several or many" and morphic as "having a form or shape" (Webster's, 1980).

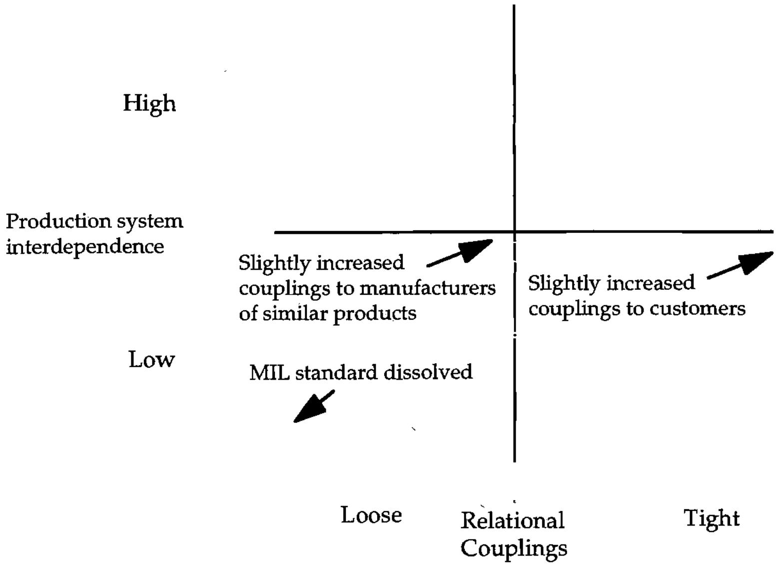

Figure 6:6: Changes in interdependence and couplings in the electronics network 1986-1995

To summarize the changes in the electronic network during the period 1986-1995 we can say that the technological interdependencies with regard to CFCs were essentially eliminated. The isomorphism with regard to CFC usage in the electronics network was completely dissolved and instead a multitude of cleaning methods were adopted, better adapted to the specific cleanliness need of the electronic product. The relative degree of inertia was thus lowered in this case. On the relationship side we argue that the couplings became slightly tighter in relation to some of the larger customers (Volvo and Saab) who soon demanded electronic products that did not use CFCs in the production process. Also, the relationships between electronic manufacturers changed in that through the TRE-project they became aware of each other and the shared interest they had, for example, in technological advancements in production techniques.

Changing positions in the network - the case of flexible foams

In the case of flexible foams, CFCs were used as a blowing agent for different PUR foam products with the largest use in the manufacturing of upholstered furniture, mattresses, and cushioning and insultation in cars.

On the supplier side there were a few large international chemical firms, some integrated forward with foam manufacturers. The foam manufacturers were few but small and did not have a strong position in their network. The users of foam products on the other hand were large firms with a very strong position relative to the foam manufacturers.

The Industrial System in Flexible Foam

The production system in the flexible foam case is somewhat harder to depict in terms of pure product or process technology. CFCs were not crucial to the product or production process but were still an integral part of the system. They were used as an ingredient to blow PUR lower density foams. The machinery in the production line to perform this task was important, of course, but could also be used without the use of CFCs. CFCs were also used to soften the surface of higher density foams. Here, CFCs in blowing was rather a technique and not an integral technology – nevertheless, if the technique was used, the product contained CFCs. Using this reasoning we could say that in relation to CFCs, the foam product was interdependent - but at a medium level. In terms of the production process, CFCs were part of an ingredient and represented one activity along the production line and were therefore interdependent but to a lower degree.

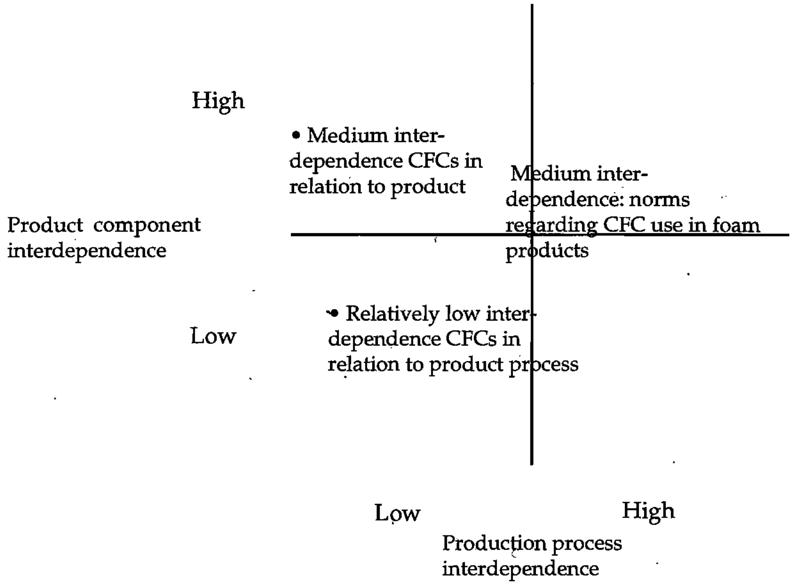

Figure 6:7: Technological interdependence in the flexible foam network, 1986

Probably more important in this case was the interdependence in the norm system on what products to produce and at what prices (see figure 6:7). The CFC blown foams were of a lower density compared to other foams and had gained market shares due to great pressures from large buyers (for example, IKEA, Saab, and Volvo) to cut prices. CFCs contributed to a larger assortment of foam products, making it possible to manufacture lighter qualities at low cost.

However, CFCs were not crucial to the functioning of the foam products but had instead been used to increase productivity (reduce input costs) by the users, and thus played an important price structuring role in this network. The heavy emphasis on price reductions had structured the production towards CFC foams and probably also contributed to institutionalize the roles of the actors in the network. The position of the manufacturers had been weakened in relation to their customers and exchange was routinized to purchasing orders, broken by occasional price negotiations. It could therefore be said that the production system was relatively highly interdependent, not in strictly technical terms but in that foams represented one part of a production chain with institutionalized logics of production efficiency and cost reducing pressures that pushed forward the lower density CFC blown foams.

The Network in Flexible Foams

The flexible foam case shows a network with relatively tight relationships, although the relative power of the actors varies greatly. The foam manufacturers had a relatively weak position and high dependency in relation to their larger and more powerful customers. Large furniture manufacturers and retailers as well as the car industry were important customers to the PUR manufacturers. The market dynamics in the PUR industry were characterized by strong price negotiations and a weak position for the PUR manufacturers relative to their larger customers.

On the supplier side a few large international firms provided foam manufacturers with suitable chemicals, knowledge on alternatives, and developed new products in the foam area. The chemicals used in the foam production were often bought in "packages" and not separate from each other. One of the two PUR manufacturers, Cirrus, was also owned by a larger chemical manufacturer and was therefore vertically integrated.

Thus, the relationships in this network as a whole could be characterized as tightly coupled with a fairly high level of interdependence between actors and the functions performed by each of them (see figure 6:8).

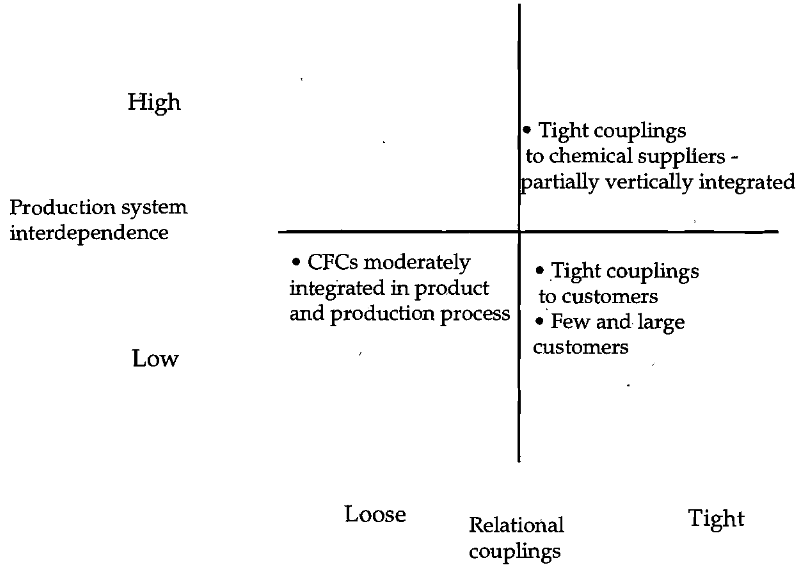

Figure 6:8: Interdependence and couplings in the flexible foam network 1986

The Isomorphism of Flexible Foams

In the flexible foam case, there were strong incentives for the PUR manufacturers to cooperate on the solution to completely stop using CFCs. By the cooperative stopping of the manufacturing of lighter quality foams (low margin qualities) and at the same time increasing prices, the PUR manufacturers could comply with the CFC phase out plan, increase profit margins, as well as strengthen their position relative to their customers. Powerful actors, customers in the network, reacted to this attempt and managed to stall the planned price increase and thereby keep the network positions unchanged. The result of the changes in the flexible foam case was a reduction in the number of available foam qualities, thus reducing flexibility and increasing the dependencies between the actors (see figure 6:9).

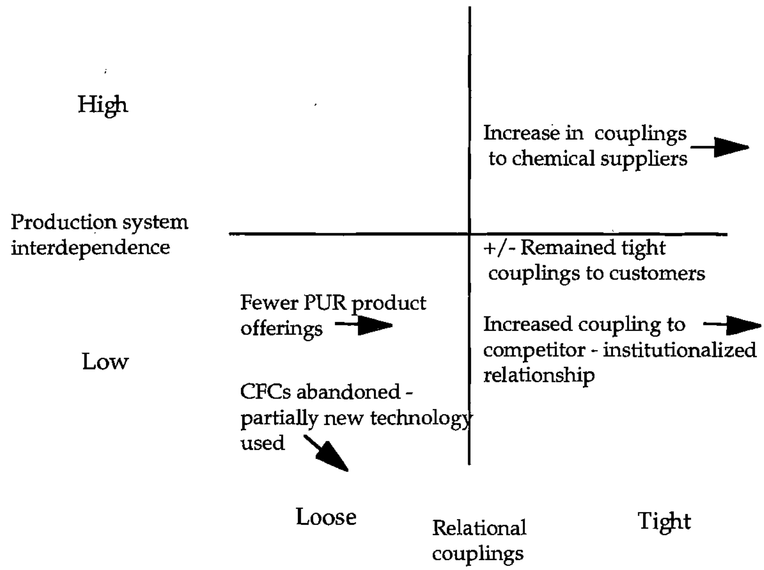

Figure 6:9: Change in interdependence and couplings in the flexible foam network 1986-1995

Thus, customers retained their strong position in this network. The suppliers improved their position relative to the foam manufacturers since some of the foam products required new "formulae " in order to fulfill the demands on softness. The PUR manufacturers were dependent on their suppliers to develop new chemical compounds that solved some of the problems when the use of CFCs was abandoned. The number of PUR product qualities offered was also reduced when CFCs were discontinued. This resulted in some lost markets, mainly small household foam products, for example dish-towels (Hawerman et al, 1995).

The forces of network dynamics and conforming strategies through institutions formed the outcome of this process. The foam manufacturers found an arena, the trade organization, where they could cooperate, both to phase out CFCs, but also try to change their position relative to their customers. The position change did not succeed but the relationship between the PUR manufacturers strengthened.

Change and Inertia in our CFC cases

As the theoretical review indicates and the cases support, inertia is evident if we focus on social change. On the one hand, there are arguably changes going on continuously in organizations and industrial systems. On the other hand, we might say about the same organization or industrial system that there exists high stability and little change. We seem to ask if change activities could be done differently, faster, and/or better. Implicitly we add elements of comparison between the studied behavior and our expectations of what behavior is appropriate in a specific situation. This indicates that there is a lag not only between the evolution and establishment of general social norms and behavioral adjustments to such norms in society as a whole, but also in our rationalization of change patterns. Perhaps our interpretations of tension in our environment and experience influence what we expect as outcomes of the resolution of such tension.

In our theoretical review we discuss the existence of such tension between the concepts of change and social inertia. Social inertia is given in the study of change. That is, we study change and look for evidence of social inertia in the process. Evidence of social inertia can be described as a relative disinclination to change current practice. We should not confuse social inertia (disinclination to change) with simple resistance to change. That is a "tendency to remain" (the physics definition of inertia from which our metaphor borrows) is not necessarily "resistance" to change. The notion of resistance in social systems reflects a more deliberate or conscious effort to reject or to counter pressures for change, while "a tendency to remain" reflects a more generalized state that can be characterized as more or less sensitive to change pressures, but not necessarily opposed to them. However, inertia in social systems can contain elements of deliberate resistance to change as we shall discuss later, but such resistance is simply an additive factor in the concept of inertia. The cause(s) or source(s) of resistance to change is independent of social inertia itself. Maintaining inertia in a given social system for certain actors who benefit from it may indeed be one of the primary causes/sources of resistance to change. Thus, understanding social inertia as something that is not interchangeable with the notion of "resistance to change" is important in understanding change processes as we will show the cases to illustrate.

Another important factor in understanding change processes is that of stability. In the inter-organizational literature, stability is perceived to be prevalent in all change processes and, according to the network approach, is a prerequisite for change to happen. That is, change is understood, and sometimes measured, in relation to stability. Stability, or the tendency for a system to have a relatively unchanging network structure, is the "counter balance" to change. The tendency to maintain stability in relational terms is the tendency for relationships (exchange, power, or otherwise) and their characteristics (tight/loose couplings, frequency of interaction, etc.) to remain the same (i.e., stable) over time.

Thus, stability affects social inertia and social inertia affects stability. Through processes of institutionalization, environmental change also adapts to prevailing network structures and norms.

Organizational rationales, network behavior and their implications for studies of environmental change

The three CFC studies suggest that to understand industrial change, environmentally hazardous activities apart, we can benefit from focusing on the network level rather than on individual organizations. Due to social inertia resulting from structure and stability of social exchange, change studies should integrate not only structural, technological and behavioral characteristics of the network, but also address how these forces relate to and/or impinge on the direction of change.

The complexity of many environmental problems, as well as ambiguity and uncertainty regarding what organizational response and solutions to adopt when faced with them and resulting pressures to change, is perhaps one of the toughest challenges facing industry today. And rather than piecemeal technological changes in individual organizations, the integration of more holistic environmental standards into strategic network behavior to ensure sustainable development remains the challenge.

Our empirical observations highlight the role of interdependencies and social inertia resulting from the technological as well as the relational systems. Through direct or indirect relationships the actors in each case organized themselves to handle pressures to change and coordinated the activities and the resources when forced to change. Characteristic of all cases were highly integrated and standardized technological systems. But the cases differed in terms of the structure (and relative structuration) of their respective networks and the patterns of change exhibited in each network. The structure of the differences can be compared in terms of their relative stability. That is, their respective tendencies to remain stable or to return to a stable state once disrupted by change pressures.

The network around refrigeration was mature and concentrated with few, large actors involving a high degree of interdependence throughout the production systems. Compared to the other networks, the degree of structuration of the refrigeration network could be characterized as greater. The flexible foam industry was also concentrated but the manufacturers were relatively small and powerless, occupying a weak position in their network of customers and suppliers. And finally, the electronic industry was highly fragmented and characterized by a strong notion of technological requirement mainly through a set of normative standards and imperatives and not by high technological system interdependence or social/relational couplings. These structural differences influenced the patterns of change that took place in each case as analyzed above.

In all cases we observed resistance to change initially and a concurrent focus on *technological* problems rather than on *environmental* problem solving. The task of change was primarily defined and structured around alternative technologies and/or available methods. Early in the refrigeration case alternatives were evaluated in relation to environmental impact, but the best performing solution, a fairly new technology, was not really considered since it would have required a large change in the production plant. The *internalization* of environmental problems into individual - or network of firms' - behavior was not observed. Instead, when forced to change, actors cooperated in finding solutions, *within established relationships*, that did not alter the existing technology and production systems to any large degree. That is we observed relatively strong inertial forces that tended to absorb pressures to change in manners that supported existing relationships among the networks of actors. In each case, pressures intended to change the behavior of actors were accommodated in such a way as to preserve stability among actors and network structures. Greater degrees of structuration often lead to greater structuration.

We found no formal observable mechanism at work that encouraged such preservation. That is to say we observed no formal policy development, rule development, or other explicit mechanism which was created or introduced in any of the cases that encouraged actors to explicitly preserve structures and equilibrium.

The pre-existing structuration (DiMaggio & Powell, 1983) of the environment carried with it institutional norms which worked to constrain perceived, competing alternatives to the CFC problem. And as we might expect the process may not have developed the most environmentally or technically optimal solutions. The solutions that emerged did not in all cases live up to long-term environmental standards, but had benefits on the organizational and network level in minimizing investments and radical changes of the production systems, i.e., preserving structures and relations both technically and socially.

Thus, internalization of environmental standards into organizational or network design was not found (which may have altered stability in some manner). On the firm and network level the patterns of responses that emerged during the change process were the diffusion and institutionalization of solutions, *not by design*[5], but through overlapping and interlocked network relations. These interlocking relationships and technologies may have *forced* individual firms to adopt a certain solution, adopted and diffused in other parts of the network, thus institutionalizing solutions within the industrial system through normative, mimetic, and coercive mechanisms. Rather the solutions to the required changes followed prevailing technological structures and were diffused through normative pressures in the exchange between engineers spanning the organizations involved in the work of replacing the CFCs.

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[5] As in carefully planned.

In addition, the paths to finding a solution were naturally constrained by the perceptions of individuals in the network of professions as well as of the industrial trade associations. Traditionally, in Sweden, trade associations are often activated by governmental intervention, or threats thereof, and organize around issues that are perceived to be of industry interest rather than of interest to a specific organization.

The prevailing pattern in all cases was that of transforming or re-framing an environmental problem and forced (legislated) change into that of a technological problem. A common pattern was also the notion of cooperation, rather than competition, among actors as the best approach to tackle environmental problems. The focus of the change process was not market-driven. Rather, the focus became one of technical specifications and industry normative practice tying over competitive boundaries. Mobilization and coordination was made in "networking" activities that worked to diffuse and legitimize chosen solutions among network members as well as in the political community.

Conclusions

Our findings in the CFCs case show differences as well as similarities in change and response patterns between industrial sectors and systems. Descriptions of the actors and relevant networks involved in the processes of change and their perceptions of the problems and possible solutions provide an interpretative background to the actual process of change. Technological interdependencies and organizational couplings are highlighted to give the system/or network a meaning. They constitute the point of departure from which the established systems changed.

Descriptions of the process of defining, solving, redefining and creating problems, the process of accepting or agreeing to solutions of those problems and how they diffuse and stabilize in the network will link the technological and organizational interdependencies with systems of values and norms. The norm system becomes illuminated through the process of problem solving which allows for analyzing the technological and organizational systems that develop out of these change processes with respect to how they get integrated with old systems or develop into new.

Based on the insights from the CFCs studies of the mobilization and coordination processes, as well as using theoretical frameworks of industrial networks, inter-organizational structure and behavior, and institutional approaches to organization, it could be argued that interdependent technologies, established industrial relationships and logics can explain variations in change and adoption patterns in the transformation towards environmentally suited products and production systems.

The presence of a well-defined environment with few actors having specialized roles and highly integrated technologies seems to create a larger degree of social inertia in the system. Stable and strongly bonded industrial systems (technological and organizational) slowly adapt to environmental demands, not by changing the industrial logic or norms, but by finding solutions that tend not to challenge or disrupt existing technological systems in production or product. In the highly structured and strongly bonded network, through processes of structuration and isomorphic pressures, one solution to the specific environmental problem of replacing CFCs was adopted and diffused.

The more loosely coupled industrial system, with a fragmented relational and technological structure, shows less stability of industrial logic and norms and a greater variability in adopting environmental solutions. Solutions, as with the stable systems, were diffused through network relationships but normative pressures regarding which environmental solution to adopt were less evident.

The result, in practice, is a fairly straightforward proposition consistent with theories of interdependent technological systems as presented earlier: the greater the impact on assembly line (production) processes of any proposed product design change, the lesser the likelihood of introducing the proposed new design changes. The corollary to this would be: in order to achieve a major product design change, the rationale (or force required to overcome inertia of existing systems) must be greater than any "counter balancing" forces to retain existing designs and their connections to existing production processes.

Chapter 7 Industrial change and sustainable development

Efforts toward changing to sustainable development in society can be understood as social and institutional responses to increasing awareness of the consequences of global changes in population growth and growing resource and energy demands of industrial activity that put increasing pressure on the earth's ecological system. To support a growing world population and the development of economic systems to support it, the demands on limited resources constantly increase, as do the polluting consequences of production and consumption. Although advanced western cultures have made great strides in solving many of our environmental waste problems by adopting cleaner technologies and production processes, the earth is still stressed beyond its carrying capacity and on a highly unsustainable course. Many global problems, such as climatic change, depletion of the ozone layer, and loss of biological diversity still remain to be solved. More local problems, such as contaminated land, air quality problems, and the lack of clean water continue to haunt nearly all regions of the globe to some extent.

This thesis has examined how social and institutional forces working for more sustainable industrial systems interact with other social and institutional forces of industrial actors and networks in the case of CFC regulations. The CFC cases show how a very technical or operational logic frames and influences how industrial actors, organizations, and entire networks approach environmental issues. An environmental issue that reflected a more generalized concern regarding the sustainability of our ecological systems became translated and operationalized in a specific industrial context into a technical logic.

The focus in all our CFC application cases became "how to replace or eliminate CFCs without causing any disruptions to existing products and processes." In these cases the issue of sustainability did not spread to corporate strategies or technological development to address environmental challenges in general. Other studies have also shown the same patterns of operational focus with re-engineering, cost-cutting and risk-reduction as primary frames for adapting to more green practices in industry (Hart, 1997).

Attempting to understand the industrial dynamics that are at work to encourage such response has been the purpose and focus of this research. The contribution then is to help to understand some of the dynamics involved in different industrial settings and how they interact with the development and possible solutions to environmental problems. Below we will review some of the findings from our theoretical review and empirical study of CFCs.

Reviewing our theoretical framing in light of our CFC case findings

This thesis has explored industrial ecological change using explanations pertaining to structures of technological and organizational systems, forces of change in networks, meaning systems (network logic and institutionalized norms), institutional differences, and how these structures, systems and forces transcend into *patterns* of change (see figure 7:1 below recapturing the field of the study). By elucidating patterns of change in industrial systems we are better able to describe, analyze, and develop models of, for example, facilitating and restraining aspects of change toward sustainability in relatively stable vs. relatively dynamic industrial systems/networks.

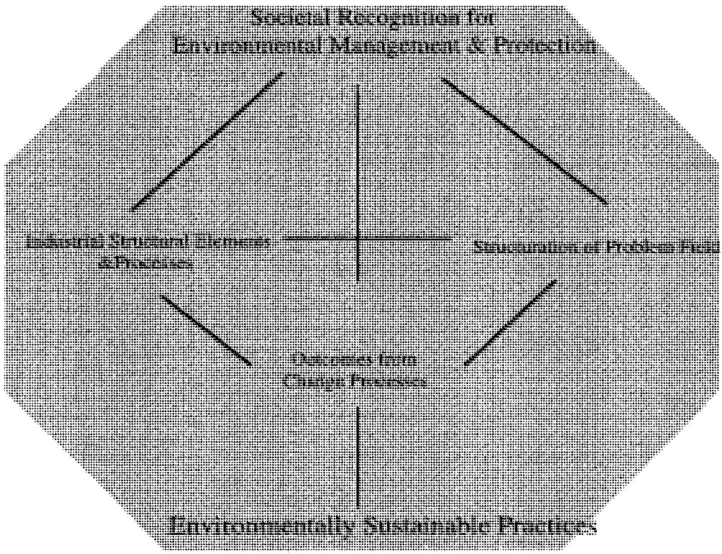

Figure 7:1: Recapturing of figure 4:1 The domain of the study

For example, if we compare our CFC applications with regard to structuration of the problem field, we can see that the CFC regulations and how industry handled the transformation to CFC-free products and production did not change the industrial structure in any major way and only temporarily. Our theoretical review suggested a more flexible change in loosely coupled networks than we actually observed in our cases. We can see evidence of a plurimorphic change in the electronic case but it has not resulted in any major structural influences. The relatively more loosely coupled system came up with multiple solutions that were adapted to local - or user specific - needs. The tightly coupled network, refrigeration, could act with force and speed only when coordinative effort was made. The solution that came about conformed to the previous technology which, in our opinion, increased the tightness of the relationships further. In this network environmental standards were not guiding the process, but rather technical and financial considerations. Production efficiency has been a norm since the early days of refrigeration production and is still prevailing.

The flexible foam case is interesting since it represents a tight network but with little interdependence in the production system in relation to CFCs.

In this case the solution was at first simply technological - a complete stop - but developed into being strategical (an attempt to change network positions) which almost changed the market and power dynamic between the actors in the network. Temporarily, the influence of the larger actors was reduced. The change process was not primarily driven by environmental concerns in this case but rather by concerns of a competitive and technological nature.

In all three cases there is evidence of inertia but in varying degrees. In the refrigeration case, with high technological interdependence and tight couplings, the relative inertia is large. When pressures came to stop using CFCs, the refrigeration network was slow to react and was initially resisting change. When change projects were started and the coordinative efforts were organized progress took place quickly. Structuration of the problem, the organizing of the change efforts and the actual solutions were following the logic and norms prevalent in the refrigeration network. Solutions were sought within existing relationships and considered technologies conformed to existing solutions. The CFC ban enhanced the inertia already prevalent in the network. The relationships between competitors strengthened and the cooperative projects around alternative technologies probably contributed to Electrolux's purchase of AEG.

In the flexible foam case the degree of inertia was medium high and was slightly increased by the process. The variation in foam products was reduced due to the CFC ban and some of the products initially had quality problems - both of which probably accelerated the restructuring of the foam industry in Sweden from 10 to 7 manufacturers (Hawerman, 1995). In the electronics case inertia in relation to norms regarding CFC use was initially prevalent but was reduced by the CFC ban. The electronic case is the only case were pluromorphic solutions came about and we believe the relative degree of inertia could be used as an explanatory variable to explain the outcome of these three change processes.

Different levels of analysis, i.e. organizational, technological, institutional, production, and network, and individual actor intentions were also problematized and analyzed as important in understanding restraints in change processes in complex systems. This thesis argues for a multi-level understanding of change processes because both theory and empirical evidence suggest that single level analysis/strategy can inform us of possible processes and outcomes of change efforts but will not likely result in change alone. For example, "simple" regulatory efforts will probably be weak in effect if they do not go beyond "changing the rules" of behaviors to a point of understanding the dynamic constraints that exist in the system. An understanding of the dynamics of (unique) industrial networks can enhance the precision of environmental policies to encourage change in sustainable directions as well as supporting industrial actors (change agents) with an analytical tool to understand the opportunities and constraints embedded in the network.

Studying change at the network level helps us to understand multiple forces forming and constraining change in the relational systems of networks. Institutional theory suggested that patterns of relations lead to isomorphic forces that influence the repertoire of organizational and individual responses to a given need or pressure for change. The institutional and network approach complement each other in that both emphasize:

1) the actions and intentions of related actors, as well as...

2) the influence of couplings and technological resource interdependencies on production systems and upon existing norm systems, can influence...

3) the direction and precision as to how we, as policy-makers, industrial strategists, or researchers, want to approach effecting or understanding change of a larger system.

Key to our theoretical integration were the processes and relationship of structuration and isomorphism, which theoretically offered some predictive power to understand patterns of activities, actor relations, and resource exchanges over time in networks with given structural properties. The notions of structuration and isomorphism help in forming an opinion on the direction of change, given certain knowledge about a given industrial network in terms of relational and technological structures and processes. The industrial network approach focuses on similar processes, those of structuration and heterogenization. If change processes are best empirically described by an elaboration of existing combinations or activities and resources, it is structuration. If they are best described by the elaboration of new combinations, it is heterogenization. The driving force for these processes is the struggle for control. When structuration occurs (as opposed to heterogenization) it occurs in two ways: 1) hierarchitisation or 2) extrication. That is, control of combinations of resources becomes increasingly centralized by fewer actors, or actors leave (extricate) themselves from the industrial network.

Succeeding to centralize a network requires intentional actions by actors to change their positions in the network, and these actions must be legitimized by other actors following some form of shared industrial logic. In the network approach, the "industrial logic" is something that "exists" and will either support or counter efforts of actors to change their positions in networks. However, the mechanisms by which the "industrial logic" is diffused during processes of structuration are not clearly identified in the network approach. The institutional approach lends itself to a more elaborate analysis of this aspect as will be discussed below. Our CFC cases suggest that how such industrial logics are diffused (and the extent to which they actually exist) is critical to understanding or anticipating the results of pressures for change from outside of a given network (i.e., the institutional environment).

By integrating theories of institutional processes of structuration and isomorphism with those of network theoretical descriptions of heterogeniety and structuration, we discover:

1) a means of anticipating or perhaps predicting the tendency towards or away from heterogenization of combinations of activities, actors and resources in industrial networks.

2) mechanisms/processes underlying the diffusion of "industrial logics,"i.e., the forces that work to coalesce perceptions and behaviors of actors like rules, norms, beliefs, frames of reference, etc., in the structuration of a network.

The institutional theoretical concepts employed to achieve this are normative, mimetic and coercive isomorphism.

Another theoretical concept we employ to help anticipate the direction of change in relation to a given pressure is that of social inertia, which we further formalize in relation to our empirical cases. We employ social inertia as a theoretical construct bridging between the network and institutional approaches since social inertia results from structuration processes and structuration processes are described in different ways by each approach (as presented in the theoretical review chapter of this thesis).

Change and inertia in our CFC cases

In the refrigeration case it was shown that technological interdependencies and relational couplings played an important role in shaping the solutions to the replacement of CFCs. Social inertia in this network was strong in all of the dimensions. The degree of structuration (social mass) was high with a tightly coupled industrial network. The endogenous forces to change existing technology towards more sustainable technology (forces to change technological "direction") were almost non-existent with a highly interdependent technological system. Taken together we can argue that the existence of a high degree of social inertia (high social density associated with intentions and coordinated actions to adhere to an existing technological path) led to isomorphic change, i.e. an industry-wide adoption of a single solution to the CFC replacement through mimetic, normative and coercive pressures.

In the case of electronics we have a different set of structures and processes that also influenced the outcome of the CFC change process. Being a loosely coupled system (less social mass) with a low degree of technological interdependence (forces for technological direction) and relatively independent actions among actors (weak driving force) in relation to CFCs, we could observe patterns of de-coupling and entrance of new actors that re-framed the norms prevalent in the industry. For example, questioning the very "practice" of cleaning the circuit boards in the first place. Low inertia, i.e. loose couplings, low technological interdependence, and little industry coordinated actions, led to plurimorphic change characterized by a variety of solutions to the replacement problem (including not to clean circuit boards at all!).

The flexible foam case shows a network with relatively tight (larger social mass) relationships where the CFC regulation was used by the foam manufacturers as a means to try to change their position relative to their suppliers and customers by setting the rules (attempts to change driving forces) for banning the CFCs. CFCs were not crucial to the functioning of the foam products but instead had been used to increase productivity (reduce input costs) by the users (mainly furniture and car manufacturers), and thus played an important price structuring role in this network. The quest for increased margins, reducing costs, higher productivity, etc., in industry in general had spurred the increased demand for CFC blown foam products, thus the norms (resulting from the prevailing industrial logic) of the production system had adapted to the lower quality and price levels made possible by the CFC blown foams. The foam manufacturers made a joint decision to abandon the CFC blown qualities and asked their customers to use the higher density qualities instead that were also more profitable for the foam manufacturers. The foam manufacturers succeeded in abandoning the lower density products but were not able to change the dynamics with tough price negotiations and ultimately their position in the network remained weak. The social inertia, in terms of relatively tight couplings, relatively low technological interdependence but high interdependence relating to the norms in the production system, was strong in this case and did not alter the network logic and structure.

Using the concept of social inertia to understand directions of change

Social inertia is proposed as a valuable analytical tool in better understanding patterns and directions of industrial development.

Following our theoretical discussion and empirical case of industrial change as a response to the chloroflourocarbon regulations we have developed a few propositions about industrial change:

> P1: An industrial network characterized by high interdependence in the production system is more likely to develop isomorphic change patterns than a network with low interdependence in the production system.
>
> P2: An industrial network characterized by low interdependence in the production system is more likely to develop plurimorphic change patterns than a network with high interdependence in the production system.
>
> P3: An industrial network with few tightly coupled actors is more likely to develop isomorphic change patterns than a loosely coupled network.
>
> P4: An industrial network with many fragmented loosely coupled actors is more likely to develop plurimorphic change patterns than a tightly coupled network.

A more formal statement regarding social inertia as being a function of a relationship between relational couplings and technological interdependencies could look like the following:

> 1. The greater the social density or mass of a network (tighter and numerous relational couplings), the greater the inertial force.
>
> 2. The greater the technological interdependencies, the greater the inertial force.

As opposed to viewing inertia as the inverse to the instantaneous rate of change as proposed by Gresov, Haveman & Oliva (1993:184), we offer a more précise and structurally measurable indication of inertial force as defined by the structuration tendencies in the network. Structuration was here described as reflecting degrees of technological interdependence and relational couplings. Thus:

Inertia = f(Technological interdependence, Degree of relational couplings)

Such a formulation further and more precisely defines inertia as a metaphor which can be used in thinking about change strategies. It also offers opportunity for the development and application of measures of technological interdependence and relational couplings (some of which are in use and fairly well developed in quantitative sociological network research and action theory, c.f. Burt, 1982 and 1987).

Implications

These propositions and formulations offer approaches to change strategies. For example, if change toward a specific end (rather than away from a specific practice) is sought, the concept and principles leading to social inertia can help us direct the change using the forces of inertia. If a network is tightly coupled (technologically and relationally) then we should first consider the nature of these couplings (number of actors, the degree to which couplings are "normative" as opposed to "technological," etc.) Then the most effective means of action can be considered. For example, creating incentives toward a specific new goal (addressing the normative elements of a network's inertial forces) as opposed to attacking existing practices (i.e., frustrating existing tech/relational couplings).

If the targeted network is loosely structured (as was the case with the electronics network) then deliberate strategies to encourage associations among different members of the network could help to coalesce efforts around developing alternative approaches to the new goals, or even modifying the goals to even greater aspirations (as happened in the electronics case).

Following the propositions above, we should avoid a limited focus on "stopping" certain behavior if we desire deeper structural change to come about. Such efforts, as we saw in the refrigeration case ultimately resulted in the adoption of a solution that seemed to satisfy the requirements of the ban, but did not alter the environmental norms of the network. In fact, it could be argued that it strengthened the norms and relations among actors, as inertia suggests. However, the ban was successful eventually, but we suggest that future efforts might be better off considering the structuration and inertial tendencies existent in a target network. If such knowledge exists, we believe policy makers can affect change faster and influence industry toward new desired outcomes rather than simply away from existing practices.

Additionally, by deliberately considering the effect of technological interdependencies present in a network, efforts to bring about change will be broadened automatically by understanding "the larger picture" or context, rather than focusing on a given technical problem. This will encourage a deliberate reckoning with a) strategies to direct change in ways that are facilitated by contextual technological interdependencies and relational couplings, or b) strategies to weaken contextual technological interdependencies and relational couplings. The first approach may actually speed-up the change processes while the later approach will require considerable force and legitimacy, which will require more time to effectuate.

Reflecting on possible future studies

In chapter 4 this study was presented as an attempt to describe and understand industrial change processes resulting from societal demands to protect the natural environment. The CFC-study has contributed with a few insights and a framing of issues based on the linking of specific change processes to a selective theoretical framework. Those insights and issues discussed above are not simple truths or the sole answer to understanding industrial change towards sustainable practices. Indeed, the findings from the study pose further questions but do represent one step towards an understanding of such complex issues as societal and industrial change towards sustainability.

The study offers insight into industrial processes that would inevitably end with the abandonment of CFC use. The regulation of the Chloroflourocarbons stipulated the ban of the chemicals by specified dates and the outcome in terms of CFC usage was therefore predictable. Still, we believe it is of interest to study cases were the outcome regarding the specific environmental problem is stipulated by the regulation. But instead of solely focusing on the abandonment of an environmentally harmful product or process we believe it is of importance to study the substantial outcome of such a regulation. What did the change result in? Are the new products or practices more environmentally apt? Have the regulations contributed towards encouraging strategic environmental development in industry?

In the present study we have only touched on these issues. One interesting research area would therefore be to further models of strategic learning in networks and models of strategic industrial network environmental development and integration. There are still uncertainties with regard to measuring environmental impact of various industrial activities but with the increased use of standardized environmental management systems in firms, for example ISO 14001 and EMAS, data will soon be available that could be integrated and used on a network level of analysis.

Another interesting research issue would be to test the framework used in this study on multiple industrial environmental change processes. Not only processes that are induced by regulation, but also market driven processes. For example, in Sweden the development of environmentally friendly detergents and organically grown food products started as a result of consumer demands. Could the processes be understood from an institutional and network change perspective? Will the propositions on iso- and pluri-morphism hold true for differently structured networks, other type of products and environmental problem-solving processes? We believe such knowledge would be of outmost value to help creating dynamic environments for reaching goals of sustainable industries and environment.

A third area of interest would be to study different means and methods aimed at influencing industry to change towards more sustainable products and practices. Are there different response patterns to different means of influence? Are some pressures/policies/methods more effective than others in stimulating industry towards sustainable development? In our case we studied industrial adaptation to a specific regulation but other environmental problems have been dealt with through volonatary industrial adaptations, for example recycling of batteries in Sweden. Are there any differences in processes and outcomes given different governance approaches to the environmental problem? What incentives and incentive structures are necessary to develop industrial capacity towards more flexible and environmentally apt systems?

A fourth, related, area of interest would be to further the knowledge on how structures could be disintegrated and changed to support industrial development towards sustainable products and practices. In the CFC-study we saw that the capacity to change could be related to the relative degree of inertia (as a function of technological interdependence and relational couplings) present in the industrial network. We believe it could be fruitful to get in-depth accounts of the individual structures and processes present in a specific change and how actors influence each other in the network to accomplish change. A greater knowledge of the intentions and tactics of the individual actors and how they interact with other actors' intentions and tactics would also add to the knowledge on how industrial systems operate in relation to pressures to change. Are some strategies more successful than others in influencing and/or enforcing change in the network?

REFERENCES

Academic and written

Alderson W. 1965. *Dynamic Marketing Behavior*. IL: Richard D. Irwin Inc.

Alderson, W. 1957. *Marketing Behavior and Executive Action*, Homewood, IL: Richard D. Irwin Inc.

AMBIO, 1990. Special Issue: CFCs and Stratospheric Ozone. *AMBIO A Journal of the Human Environment*. Vol XIX No 6-7, October 1990.

Anderson, H. 1994. *Ett Industriföretags Omvandling*. Published Ph.D. Thesis. Stockholm: Stockholm School of Economics, EFI.

Andersson P. 1996. *Concurrence, Transition and Evolution. Perspectives of Industrial Marketing Change Processes*. Published Ph.D. Thesis. Stockholm: Stockholm School of Economics, EFI.

Andersson, P. 1992. Analysing Distribution Channel Dynamics: Loose and Tight Coupling in Distribution Networks. *European Journal of Marketing*, Vol. 26, No 2, pp.47-68.

Axelrod, R. 1984. *The Evolution of Cooperation*. New York: Basic Books.

Axelsson, B. & Easton G. (eds), 1992. *Industrial Networks - A New View of Reality*. London: Routledge.

Axelsson, B. 1992. Corporate Strategy Models & Networks - diverging perspectives. In: B. Axelsson & G. Easton (eds), *Industrial Networks - A New View of Reality*. London: Routledge, pp.184-204.

Azzone, G. & Manzini, R. 1994. Measuring Strategic Environmental Performance. *Business Strategy and the Environment*. Vol. 3:1, pp.1-14.

Bebbington , J & Gray, R. 1993. Corporate Accountability and the Physical Environment: Social Responsibility and Accounting Beyond Profit. *Business Strategy and the Environment*. Vol. 2:2, pp.1-11.

Belz, F. 1997. GRI report on industry and the environment. Gothenburg: Gothenburg Research Institute.

Bergman, L. (ed), 1989. *Värdera miljön!* Stockholm: SNS

Bergman, L. 1995. Simple observations on the "green firm". In: Wolff R. & B. E. Ytterhus (eds), *Environmental Management - Where do we stand*? Norway: Cappelen Akademisk Forlag as.

Bijker, W. E., Hughes, T. P. & Pinch, T. 1987. 3rd ed 1990. *The Social construction of Technological Systems - New directions in the sociology and history of technology*. Cambridge, Massachusetts: The MIT Press.

Brinckerhoff, R.F., Cross, J.B. & Lazarus, A. 1959. *Exploring Physics*. New York: Harcourt, Brace and Co.

Brown, L.A. 1981. *Innovation Diffusion: A New Perspective*. London: Methuen.

Burt, R.S. 1982. *Toward a Structural Theory of Action: Network Models of Social Structure, Perception and Action*. New York: Academic Press.

Burt, R.S. 1987. Social contagion and innovation: Cohesion versus structural equivalence. *Amercian Journal of Sociology*. Vol. 92, pp. 1287-1335.

Carlsson, A., 1989. Alternativ kylteknik i USA. Report 8916 Sveriges Tekniska Attacheér, Washington, DC.

Carson, R. 1991. Silent Spring. In *The Green Reader - Essays Toward a Sustainable Society*. Dobson, A. (eds.). San Francisco: Mercury House Inc.

Cohen, M.D., March, J.G. & Olsen. J.P. 1972. A Garbage Can Model of Organizational Choice. *Administrative Science Quarterly,,* Vol.17, pp. 1-25.

Contractor, F.J. & Lorange. P. (eds), 1988. *Cooperative Strategies in International Business;.* Lexington, MS: Lexington Books.

Cowan, R. & Hultén, S. 1996. Escaping Lock: The Case of the Electric Vehicle. *Technological Forecasting and Social Change - An International Journal.* Volume 53, No 1, September, pp. 61-79.

Crutzen, P. 1970. The Influence of Nitrogen Oxides on the Atmospheric Ozone Content. *Quartely Journal of the Royal Meteorological Society* 97:320-25.

Dagens Industri, 1992. Electrolux och Greenpeace kan inte enas om kylskåp. October 20.

Dagens Industri, 1993. Lux tvåa i kylskåps-VM. 30 juni.

Dahmén, E. 1950. *Svensk Industriell Företagarverksamhet - kausalanalys av den industriella utvecklingen 1919-1939.* Stockholm: Almqvist & Wiksells Boktryckeri AB.

Dahmén, E. 1968. *Sätt Pris på Miljön. - Samhällsekonomiska Argument i Miljöpolitiken.* Stockholm: SNS, Studier och Debatt Nr 3, 16:e årg.

Daly, H. E. 1993. Essays toward a Steady State Economy. In: *Valuing the Earth..* H. Daly & M. Townsend (eds.) Cambridge, MA: The MIT Press.

David, P.A. 1985. Clio and the Economics of Qwerty. *American Economic Review* No 75, pp. 332-337.

DiMaggio P. & Powell, R. 1983. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields, *American Sociological Review,* Vol. 48, pp. 147-160.

DiMaggio, P. 1986. Structural Analysis of Organizational Fields: A Blockmodel Approach. In L.L. Cummings & B. Staw (eds):*Research in Organizational Behavior,* pp. 335-370. Vol. 8 Greenwich.

DiMaggio, P. 1993. Nadel's Paradox Revisited: Relational and Cultural Aspects of Organizational Structure. In Nohria, N. & R.G. Eccles (eds). *Networks and Organizations: Structure Form and Action.* pp. 118-142. Cambridge: Harvard Business School Press.

Dobson, A. (ed) (1991). *The Green Reader - essays toward a sustainable society.* San Francisco: Mercury House Inc.

Easton, G. & Araujo, L. 1992. Non-economic Exchange in Industrial Networks. In Axelsson, B. & G. Easton (eds), *Industrial Networks. A New View of Reality.,* pp. 62-84. London: Routledge.

Federation of Swedish Industries, 1987. Avvecklingsprogram för CFC-användning. *Promemoria 1987-12-22.*

Federation of Swedish Industries, 1990. *Saving The Ozone Layer - a global task.* Publication of a joint project between The Swedish Society for the Conservation of Nature, The Confederation of Trade Unions in Sweden, Federation of Swedish Industries, The Swedish Council for Planning and Coordination of Research, Swedish EPA, The Swedish International Development Authority, Royal Swedish Academy of Engineering Sciences, and The Royal Swedish Academy of Sciences. Stockholm.

Fisk, G. 1978. Possible Futures of Marketing. In: G. Fisk, J. Arndt & K. Grønhaug, *Future Directions for Marketing.* Proceedings of Two European Colloquia April 1976 & May 1977 Report No. 78-104, pp. 2-3. Cambridge, MA: Marketing Science Institute.

Fligstein, N. 1991. The Structural Transformation of American Industry: An Institutional Account of the Causes of Diversification in the Largest Firms, 1919-1979. In Powell, W.W. & P. J. DiMaggio: *The New Institutionalism in Organizational Analysis* pp. 311-336. Chicago: The University of Chicago Press.

Frederick, J. E. 1986. The Ultraviolet Radiation of the Biosphere. In Titus (ed): *Effects of Changes in Stratospheric Ozone and Climate Change.* Washington: Environmental Protection Agency, pp. 121-128.

Fri Köpenskap, 1992. ICA testar kyla utan freoner. October 2, p.19.

Gadde, L-E & Mattsson L-G. 1987. Stability and Change in Network Relationships. *International Journal of Research in Marketing* Vol.4, pp. 29-41, North Holland.

Gadde, L-E. & H. Håkansson, 1992. Analyzing Change and Stability in Distribution Channels - A Network Approach. In Axelsson, B. & G. Easton (eds), *Industrial Networks, - A New View of Reality.* pp. 166-179. London: Routledge.

Gancher, D., 1991. Foreword in: Dobson, A. (ed): *The Green Reader - essays towad a sustainable society.* San Francisco: Mercury House Inc.

Giddens, A. 1976. *New Rules of Sociological Methods.* New York: Basic Books.

Giddens, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration.* Cambridge, Polity Press/Berkeley: University of California Press.

Glassman, R.B. 1973. "Persistence and Loose Coupling in Living Systems", *Behavioral Science,* Vol. 18, pp. 83-89.

Granovetter, M. 1985. Economic Action and Social Structure: The Problem of Embeddedness. *American Journal of Sociology,* Vol. 91, No 3, pp. 3-11.

Gray, R. 1993. *Accounting for the Environment.* London: Paul Chapman Publishing Ltd.

Gresov, C., Haveman, H. A. & Oliva, T. A. 1993. Design, Inertia and Dynamics of Competitive Response. *Organization Science.* vol. 4, No 2 May, pp. 181-208.

GRI & Bedriftsøkonomens Forlag A/S, 1995. *The Nordic Environmental Business Barometer.*

Gullers, K. 1983. The Munters Story. Stockholm: Gullers Pictorials.

Hannan, M. & Freeman, J. 1989. *Organizational Ecology.* Cambridge, MA: Harvard University Press.

Hart, S. L. 1997. Beyond Greening: Strategies for a Sustainable World. *Harvard Business Review,* January-February, pp. 66-76.

Hawerman L., Nordin, C. & Östman, A. 1995. Utvärdering av ODS-avvecklingen: tekniker och alternativ. Stockholm: Naturvårdsverkets Förlag. Rapport 4478.

Helgesen, T. 1978. Consumers' market power as an instrument of environmental protection policy. In: G. Fisk, J. Arndt & K. Grønhaug, *Future Directions for Marketing.* Proceedings of Two European Colloquia April 1976 & May 1977, pp. 312-319. Cambridge, Massachusetts: Marketing Science Institute.

Henders, B. 1992. *Positions in Industrial Networks - Marketing Newsprint in the UK.* Published Ph.D. thesis. Uppsala: Uppsala University.

Henion, K. E. 1978. Ecological Marketing: Will the normative model become descriptive? In: G. Fisk, J. Arndt & K. Grønhaug, *Future Directions for Marketing.* Proceedings of Two European Colloquia April 1976 & May 1977, pp. 301-311. Cambridge, Massachusetts: Marketing Science Institute.

Hertz, S. 1992. Towards more integrated industrial systems. In Axelsson, B. & G. Easton (eds), *Industrial Networks, - A New View of Reality.* pp. 105-128. London: Routledge.

Hertz, S. 1993. *The Internationalization processes of freight transport companies: Toward a dynamic network model of internationalization.* Published Ph.D. thesis. Stockholm: Stockholm School of Economics, EFI.

Hirsch, P. M. 1975. Organizational Effectiveness and the Institutional Environment, *Administrative Science Quarterly* Vol. 20, pp. 327-344.

Hirtz J. & Uhlig, J. 1985. Polyurethanes and their Market. In: G. Oertel (ed), *Polyurethan Handbook.* 1st Ed.

Hoffman, J.S. 1990. Replacing CFCs: The Search for Alternatives. *AMBIO, A Journal of the Human Environment*, Vol XIX no 6-7, pp. 329-333.

Hrebiniak, L. G., Joyce, W. F & Snow, C.C. 1989. Strategy, Structure, and Performance: Past and Future Research. In Charles C. Snow (ed). *Strategy, Organization Design, and Human Resource Management.* Greenwich: JAI Press Inc.

Hultén, S. & Östlund*, S. 1994. Miljöanpassning - drivkraft för industriell utveckling. In: Mattsson L. G. & S. Hultén (eds). *Företag och marknader i förändring - dynamik i nätverk.* Stockholm: Nerenius & Santérus Förlag, pp. 44-60.

Hylander, H. 197?. Ett kylskåps historia. Archival 564a at The Swedish Technology Museum. Teknikhistoriska notiser, pp. 134-142.

Håkansson, H. & Waluszewski, A. 1997. Recycled Fibre Turning Green. In Gemünden, H. G., T. Ritter & A. Walter (eds). *Relationships and Networks in International Markets.* Oxford, UK: Elsevier Science Ltd, pp. 390-410.

Håkansson, H. & Snehota, I. (eds), 1995. *Developing Relationships in Business Networks.* London: International Thomson Business Press.

Håkansson, H. & Johanson, J. 1988. Formal and Informal Cooperation Strategies in International Industrial Networks. In F.J. Contractor & P. Lorange, (eds). *Cooperative Strategies in International Business,.* Lexington, MS: Lexington Books, pp. 369-379.

Håkansson, H. & Johanson, J. 1992. A model of Industrial Networks. In Axelsson, B. & G. Easton (eds), *Industrial Networks,. A New View of Reality.* London: Routledge, pp. 205-234.

Håkansson, H. (ed), 1982. *International Marketing and Purchasing of Industrial Goods. An Interaction Approach.* Chichester: John Wiley & Sons.

Hägg, I. & Johanson, J. (Eds), 1982. *Företag i Nätverk - ny syn på konkurrenskraft.* Stockholm: Studieförbundet Näringsliv och Samhälle.

International Institute of Refrigeration, 1990. 6th Informatory Note on CFCs and Refrigeration. Paris: November.

IVF. 1990. Rekommendation från TRE-projektet rörande alternativ till CFC-användning som tvättvätska inom elektonikindustrin. *IVF Report 1990-08-25. BB/TRE2.*

Jachtenfuchs, M. 1990. The European Community and the Protection of the Ozone Layer. *Journal of Common Market Studies.* Vol XXVIII, No 3. March, pp. 260-277.

Johanson, J. & Mattsson, L-G. 1985. Marketing Investments and Market Investments in Industrial Networks. *International Journal of Research in Marketing,* Vol. 2, pp. 185-195.

Johanson, J. & Mattsson, L-G. 1991. Strategic Adaptation of Firms to the European Single Market: A Network Approach. In: L-G Mattsson, & B. Stymne (eds.). *Corporate and Industry Strategies for Europe.* Amsterdam: North-Holland, Advanced Series in Management Vol. 15, pp. 263-281.

Johanson, J. & Mattsson, L-G. 1992. Network positions and strategic action - an analytical framework. In: B. Axelsson & G. Easton (eds.). *Industrial Networks - a New View of Reality,* pp. 205-217. London: Routledge.

Johanson, J. & Mattsson, L-G. 1985. A note on the characteristics of inter-organizational relations in industrial systems - a network approach compared to the transaction cost approach. Paper presented at *EGOS Conference* in Saltsjöbaden, Sweden. 12-14 juni, 1985.

Kemp, R., Schot, J., & Hoogma, R. 1998. Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. *Technology Analysis & Strategic Management,* Vol. 10, No 2, pp. 175-195.

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Krackhardt, D. 1992. The Strength of Strong Ties: The Importance of *Philos* in Organizations. In N. Nohria, & R.G. Eccles (eds). *Networks and Organizations: Structure Form and Action.* 216-239. Cambridge: Harvard Business School Press.

Litfin, K. T. 1994. *Ozone Discourses. Science and Politics in Global Environmental Cooperation.* New York: Colombia University Press.

Lovelock, J. 1973. Halogenated Hydrocarbons in and over the Atlantic. *Nature* 241, pp.194-196.

Lundgren, A. 1991. *Technological Innovation and Industrial Evolution..* Published Ph.D Thesis. Stockholm: Stockholm School of Economics, EFI.

Lundgren, A. 1992. Coordination and Mobilization Processes in Industrial Networks. In: B. Axelsson & Easton G. (eds). *Industrial Networks - A New View of Reality.* London: Routledge Ltd.

Lundgren, A. 1995. *Technological Innovation and Network Evolution.* London: Routledge.

Lydersen, S. 1977. Resursregnskap. *Bedriftsökonomen*, no 9, pp. 462-467.

Lönnroth, M. 1995. Miljöpolitiken - en drivkraft i näringslivets moderninsering och utveckling. In: *Miljön som resurs.* Rapport från Näringsdepartementets Struktursekretariat.

March, J. G. & Simon, H. A. 1958. *Organizations.* New York: John Wiley & Sons.

Mattsson L-G. 1997. The Market-as-Networks Approach and Economic Sociology. In F. Mazet, R. Salle & J-P. Valla: Interaction, Relationships and Networks in Business Markets. *Proceedings of the 13th international conference on Industrial Marketing and Purchasing.* Lyon, September 4-6, pp. 253-267.

Mattsson, L-G. 1989. Developments of firms in networks: positions and investments. *Advances in International Marketing*, Vol. 3, pp. 121-139.,

Mattsson, L-G. 1995. Firms, "Megaorganizations" and Markets: A Network View. *Journal of Institutional and Theoretical Economics (JITE).* 151/4. pp. 760-766.

Mattsson, L-G. 1987. Managment of Strategic Change in a 'Market-as-Networks' Perspective. In Pettigrew, A (ed): *The Managment of Strategic Change.* John Wiley & Sons, Basil Blackwell, Great Britain.

Meyer, J. W. & Scott, R. W. (eds), 1992. *Organizational Environments. Ritual and Rationality.* Newbury Park: Sage Publications.

Meyer, J. W., J. Boli, & Thomas, G. M. 1994. Ontology and Rationalization in the Western Cultural Account. In Scott, R. W., J. W. Meyer (eds) and Associates: *Institutional Environments and Organizations. Structural Complexity and Individualism..* Thousand Oaks, CA: Sage Publications, pp. 9-27.

Ministry of Environment, Swedish Government, 1987. Environmental Prop. 1987/88:85

Ministry of Environment, Swedish Government, 1991. Environmental Prop. 1990/91:90: *En God Livsmiljö.* Stockholm: Norstedts Tryckeri.

Ministry of Environment, Swedish Government, 1989. Svensk miljöpolitik i ett västeuropeiskt perspektiv - en jämförelse mellan Sveriges och EG:s regler på miljöområdet. Fakta Europa 1989:1

Ministry of Environment, Swedish Government, 1992. The Swedish Environment. Annex to Sweden: National report to UNCED 1992.

MIT, 1993. Dimensions of Managing Chlorine in the Environment. Report of The M.I.T./Norweigian Chlorine Policy Study. Technology, Business and Environment Program, Massachusetts Institute of Technology. MIT March.

Moore, C.A. 1990. Industry Responses to the Montreal Protocol. *AMBIO A Journal of the Human Environment*, Vol XIX no 6-7, 320-323.

Mäler, K. G. 1980. Miljö och ekonomi. *Ekonomisk Debatt*, vol. 8:2 pp. 98-106.

Mäler, K. G. 1984. Nya ekonomiska styrmedel i miljöpolitiken. *Ekonomisk Debatt*, vol 12:7 pp. 442-450.

Nadler, D. & Tushman, M. 1988. *Strategic Organization Design. Concepts, Tools, & Processes.* Glenview, Illinois: Scott, Foresman and Company.

Nohria, N. & Eccles, R.G. (eds). 1993. *Networks and Organizations: Structure Form and Action..* Cambridge: Harvard Business School Press.

Nordic Council of Ministers (1992). CFC-Free Technology in the Plastic Foam Sector - a catalogue from the Nordic countries. Nord 1992:42

Nordic Council of Ministers (1993). Metal Degreasing and the Ozone Layer. Nordiske Seminar-og ARbejd-rapporter. 1993:607.

Nordic Council of Ministers (1993). Methyl Bromide in the Nordic Countries - current use and alternatives. Nord 1993:34

Nordic Council of Ministers, 1993. Metal Degreasing and the Ozone Layer. *Nordiske Seminar-og Arbejdsrapporter 1993:607.*

Nyström, T. 1991. Preliminära tester av CFC-ersättare visar på problem. Sveriges Tekniska Attacher Notis no: U2-91-127. Stockholm, 1991-08-02.

Omrcen, E. 1992. Environmentally Adjusted Product Development - a study of local change. *EIASM Conference on International Product Development* - New Approaches to Devlopment and Engineering.

Omrcen, E. 1992b. Förebyggande miljöskyddsstrategi och miljöanpassad produktutveckling. In: Bergström & Lothigius (eds). Företagsekonomisk Miljöforskning - rapport från en konferens. *Research Report R 1992:7* Stockholm: University of Stockholm, Dept. of Business Administration. pp. 79-83.

Parsons, T. 1951/1964. *The Social System.* New York: The Free Press/London: Collier-Macmillan Ltd.

Parsons, T. 1977. *Social Systems and the Evolution of Action Theory.* New York: The Free Press.

Peattie, K. 1992. *Green Marketing.* London: Pitman Publishing.

Perrow, C. 1986. *Complex Organizations.,* New York: Random House.

Pfeffer, J. & Salancik, G.R. 1978. *The External Control of Organizations: A Resource Dependence Perspective.* New York: Harper & Row, Publishers.

Powell, W.W. & DiMaggio, P.J. 1991. *The New Institutionalism in Organizational Analysis.* Chicago: The University of Chicago Press.

Roome, N. & Hinnells, M. 1993. Environmental Factors in the Management of New Product Development: theoretical framework and some empirical evidence from the white goods industry. *Business Strategy and the Environment.* Vol. 2:2.

Schelling, T.C. 1978. *Micromotives and Macrobehavior.* W.W. Norton & Company Inc.

Schumpeter, J. 1939. *Business Cycles I-II.* New York & London.

Scott, R. W. & Christensen S. (eds), 1995. *The Institutional Construction of Organizations - International and Longitudinal Studies.* Thousand Oaks: Sage Publications.

Scott, R. W. 1995. Introduction. Institutional Theory and Organizatons. In: Scott & Christensen, eds. *The Institutional Construction of Organizations - international and longitudinal studies.* Thousand Oaks: Sage Publications. pp. xi-xxiii.

Scott, R. W., Meyer, J. W. and Associates. 1994. *Institutional Environments and Organizations. Structural Complexity and Individualism..* Thousand Oaks, CA: Sage Publications.

Scott, W. R. 1992. From Technology to Environment. In: S. Meyer & R. Scott (eds). *Organizational Environments. Ritual and Rationality.* Newbury Park: Sage Publications. pp. 13-17.

Scott, W.R. 1987a. *Organizations - Rational, Natural and Open Systems.* Englewood Cliffs: Prentice Hall Inc. Second Edition.

Scott, W.R. 1987b. The Adolescence of Institutional Theory. *Administrative Science Quarterly,* 32:493-500.

Selznick, P. 1957. *Leadership in Administration,* New York: Harper & Row.

Shrivastava P. 1992. Corporate Self-greenewal: strategic responses to environmentalism. *Business Strategy and the Environment.* Vol. 1:3, pp. 9-21.

Shrivastava P. 1995. Econcentric management for a crisis society. In: Wolff R. & Ytterhus, B. E. *Environmental Management - Where Do We Stand?* Norway: Cappelen Akademisk Forlag as.

Shrivastava, P. & Hart, S. 1995. Creating Sustainable Corporations. *Business Strategy and the Environment.* Vol. 4:3, pp.154-165.

Simon, H. A. 1976. *Administrative Behavior,* 3rd ed. New York: Free Press.

SNV. (1989). Naturvårdsverket Informerar. Din kylanlägging - skötsel och underhåll.

SNV. 1987. Naturvårdsverket informerar. Hur ska vi ta hand om gamla kylskåp?

SNV. 1988 Allmäna Råd 88:5. Kylanläggningar och värmepumpar med CFC/HCFC.

SNV. 1990 Rapport 3717. Alternativ till 1,1,1-trikloretan för avfettning/rengöring och elektronik.

SNV. 1991 Rapport 4316. Sweden free from ozone-depleting substances.

SNV. 1991 Rapport 3979. Erfarenheter från CFC-avvecklingen - utvärdering om användningen av CFC-, HCFC som köldmedium.

SNV. 1991 Report 4032. A study of the use of HCFCs as insulating gas in polymeric materials in comparison with other alternatives.

SNV. 1991. Naturvårdsverket Informerar. Erfarenheter av CFC-avvecklingen.

SNV. 1991. Swedish EPA Informs. Experience from the CFC phase-out.

SNV. 1992 Rapport 4020. Erfarenheter från CFC-avvecklingen - nu teknik i kyl- och värmeanläggningar.

SNV. 1992 Rapport 4145. Ytterligare styrmedel för HCFC.

SNV. 1994 Rapport 4278. Sverige fritt från ozonnedbrytande ämnen.

SNV. 1995 Rapport 4475. Utvärdering av ODS-avvecklingen - Utvärdering av ekonomiska konsekvenser.

SNV. 1995 Rapport 4476. Utvärdering av ODS-avvecklingen - Halon som släckmedel.

SNV. 1995 Rapport 4477. Utvärdering av ODS-avvecklingen - Strategianalys.

SNV. 1995 Rapport 4478. Utvärdering av ODS-avvecklingen - tekniker och alternativ.

SNV. 1995. Svensk avveckling av ozonuttunnande ämnen - en utvärdering.

SNV. The Swedish EPA - Svenska Naturvårdsverket, 1989 Rapport 3747. Teknisk granskning av den kemiska användningen av 1,1,1-trikloretan och koltetraklirid samt möjligheterna att ersätta och avveckla ämnena.

SPK. 1987. Marknaden för elektriska hushållsapparater: struktur och konkurrens. SPKs utredningsserie 1987:19.

Statens Industriverk. 1991. 660 Plastföretag - enkätundersökning i svensk plastindustri. Report March 1991.

Swedish Forest Industry Association. 1997a. *The Forest Industry, the Ecocycle and the Environment - a summary.* Stockholm: Swedish Forest Industry Association.

Swedish Forest Industry Association. 1997b. *From Frog to Prince.* Stockholm: Swedish Forest Industry Association.

Söderbaum P. 1973. *Positionsanalys vid beslutsfattande och planering. ekonomisk analys på tvärvetenskaplig grund.* Stockholm: Esselte Studium, Scandinavian University Books.

Söderbaum P. 1995. *Ekologisk Ekonomi - miljö och utveckling i ny belysning.* Lund: Studentlitteratur.

Sölvell, Ö. 1989. Structural Evolution in the White Goods Industry. Case study published by the Institute of International Business, IIB, at Stockholm School of Economics. Ver. 3 10/90.

Sørensen, T. 1988. Vestfrost I 25 år - 1963-1988. Esbjerg: A/S Vestfrost.

Teece, D.J. 1992. Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organization,* Vol. 18, pp. 1-25.

Thompson, J.D. 1967. *Organizations in Action: Social Science Bases of Administrative Theory,* McCraw-Hill, New York.

Turner, R.K. 1993. Sustainability: principles and practices. In Turner, R.K. (ed): *Sustainable Environmental Economics and Management: principles and practices.* London: Belhaven Press. pp.-36.

U.S. EPA, 1999. Proceedings, of the EPA TIER 2 EMISSION STANDARDS 5 FOR VEHICLES AND GASOLINE SULFUR STANDARDS, June 10th.

Ullstrand, H. 1961. Kylskåpet utan motor blev världsindustri. . In: Svenska Uppfinnarföreningen: *Från Idé till Produkt.* 75th Anniversary Publication. Köping: Reklamtryckeriet.

UNEP. 1987. *Montreal Protocol on Substances that Deplete the Ozone Layer,* Final Act.

UNEP. 1990. Report of the secretariat on the reporting of data by the parties in accordance with article 7 of the Montreal Protocol. First Meeting, Nairobi 6-7 December.

UNEP. 1991. Report of the secretariat on the reporting of data by the parties in accordance with article 7 of the Montreal Protocol. Second Meeting, Geneva 11-12 April.

UNEP. 1992. Report of the secretariat on the reporting of data by the parties in accordance with article 7 of the Montreal Protocol. Fourth Meeting, Copenhagen 23-25 November.

UNEP. 1993. Halons - a special supplement of OzonAction. Newsletter September.

UNEP. 1994. OzonAction no 10. Newsletter March.

Van de Ven, A. H. & Joyce, W. F. 1981. *Perspectives on Organization Design and Behavior.* John Wiley & Sons, Inc.

Veblen, T. 1904. *Theory of the Business Enterprise.* New York.

Walton, R.E. 1987. *Innovating to Compete: Lessons for Diffusing and Managing Change in the Workplace.* San Francisco: Jossey-Bass.

WCED. 1987. *Our Common Future.* World Commission on Environment and Development. Oxford: Oxford University Press.

Weber, M. 1968. *On Charisma and Institution Building - selected papers.* Chicago: The University of Chicago Press.

Webster's New World Dictionary. 1980. Second College Ed. Cleveland, Ohio: William Collins Publishers Inc.

Weick, K. E. 1976. "Educational Organizations as Loosely Coupled Systems", *Administrative Science Quarterly*, Vol. 21, pp. 1-19.

Weick, K.E. 1979. *The Social Psychology of Organizing*, Addison-Wesley, Reading, 2nd ed..

Weick, K.E. 1982. "Management of Organizational Change among Loosely Coupled Elements". In Goodman, P.S. & Associates (eds.), *Change in Organizations*, San Francisco: Jossey-Bass, pp. 375-408.

Welford, R. & Jones, D. 1995. Towards the sustainable business organisation. In: R.Wolff & B. E. Ytterhus (eds) *Environmental Management - Where do we stand?* Norway: Cappelen Akademisk Forlag as.

White, R. & Hurst, D. (eds), 1994. *Building the Strategically-Responsive Organization* (pp. 351-369). John Wiley & Sons Ltd.

Wolff R. & Ytterhus, B. E. (eds), 1995. *Environmental Management - Where do we stand?* Norway: Cappelen Akademisk Forlag as.

Zaring, O. 1999. Investment Decisions and the Environment - a study of strategies for project planning. Published PhD thesis. Gothenburg: Gothenburg University.

Zucker, L. 1987. Institutional Theories of Organizations, *Annual Review of Sociology*, 13:443-464.

Östlund* , S. & Larsson, R. 1994. The Greening of Strategic Alliances - The Institutionalization of Environmental Compliance. In H. Thomas, D. O'Neal, R. White & D. Hurst (eds): *Building the Strategically-Responsive Organization* (pp. 351-369). John Wiley & Sons Ltd.

Östlund*, S. 1994. The Limits and Possibilities in Designing the Environmentally Sustainable Firm. *Business Strategy and the Environment, Vol 3., No 2,*. (pp. 21-33).

Östlund, S. & Roome, N. 1998. Sustainable Forestry Management as a Model for Sustainable Industry: a case study of the Swedish approach. In N. Roome (ed): *Sustainability Strategies for Industry - the future of corporate practice.* Washington, D.C.: Island Press, pp. 203-221.

Interviews

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Company printed materials

Dannfoss: Information materials

Du Pont. Information materials

Electrolux:
- Annual Reports 1925-1992
- Information materials
- (1988). Axel Wennergren & Hans Werthen: Två epoker som format en världkoncern. Stockholm: Electrolux, December.
- (1991). Elextrolux Historien. Stockholm: Electrolux.

SPF, Swedish Plastics Federation, 1986-1991. Protocols from CFC group board meetings at The Swedish Plastics Federation.

Svensk Freonåtervinning AB (1992). Ny teknik i Sverige - freonåtervinning ur kyl- och frysar. Information leaflet.

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2000

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1999

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Eliasson, A-C., Smooth Transitions in Macroeconomic Relationships.
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Helgesson, C-F., Making a Natural Monopoly: The Configuration of a Techno-Economic Order in Swedish Telecommunications.
Japanese Production Management in Sunrise or Sunset. Christer Karlsson (editor).
Jönsson, B., Jönsson, L., Kobelt, G., Modelling Disease Progression And the Effect of Treatment in Secondary Progressive MS. Research Report.
Lindé, J., Essays on the Effects of Fiscal and Monetary Policy.
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Sjöstrand, S-E., Sandberg, J., Tyrstrup, M., (red) Osynlig Företagsledning.
Skalin, J., Modelling Macroeconomic Time Series with Smooth Transition Autoregressions.
Spagnolo, G., Essays on Managerial Incentives and Product-Market Competition.
Strauss, T., Governance and Structural Adjustment Programs: Effects on Investment, Growth and Income Distribution.
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1998

Andersson, M., On Testing and Forecasting in Fractionally Integrated Time Series Models.
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Berg-Suurwee, U., Nyckeltal avseende kultur- och fritidsförvaltning innan stadsdelsnämndsreformen.
Bergström, F., Essays on the Political Economy of Industrial Policy.
Bild, M., Valuation of Takeovers.
Charpentier, C., Samuelson, L.A., Effekter av en sjukvårdsreform – en analys av Stockholmsmodellen.
Eriksson-Skoog, G., The Soft Budget Constraint: The Emergence, Persistence and Logic of an Institution. The Case of Tanzania 1967-1992.
Gredenhoff, M., Bootstrap Inference in Time Series Econometrics.
Ioannidis, D., I nationens tjänst? Strategisk handling i politisk miljö – en nationell teleoperatörs interorganisatoriska, strategiska utveckling.
Johansson, S., Savings Investment, and Economic Reforms in Developing Countries.
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Ljunggren, U., Styrning av grundskolan i Stockholms stad innan stadsdelsnämndsreformen.
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Olsson, P., Studies in Company Valuation.
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Roszbach, K., Essays on Banking Credit and Interest Rates.
Runsten, M., The Association Between Accounting Information and Stock Prices. Model development and empirical tests based on Swedish Data.
Segendorff, B., Essays on Bargaining and Delegation.
Sjöberg, L., Bagozzi, R., Ingvar, D.H., Will and Economic Behavior.
Sjögren, A., Perspectives on Human Capital: Economic Growth, Occupational Choice and Intergenerational Mobility.
Studier i kostnadsintäktsanalys, red Jennergren, P.
Söderholm, J., Målstyrning av decentraliserade organisationer. Styrning mot finansiella och icke-finansiella mål.
Thorburn, K., Cash Auction Bankruptcy and Corporate Restructuring
Wijkström, F., Different Faces of Civil Society.
Zethraeus, N., Essays on Economic Evaluation in Health Care. Evaluation of Hormone Replacement Therapy and Uncertainty in Economic Evaluations.

1997

Alexius, A., Essays on Exchange Rates, Prices and Interest Rates.
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Ericsson, J., Credit Risk in Corporate Securities and Derivatives. Valuation and Optimal Capital Structure Choice.
Charpentier, C., Budgeteringens roller, aktörer och effekter. En studie av budgetprocesserna i en offentlig organisation.

De Geer, H., Silfverberg, G., Citizens'Trust and Authorities' Choices, A Report from The Fourth International Conference on Ethics in the Public Service, Stockholm June 15-18, 1994.
Friberg, R., Prices, Profits and Exchange Rates.
Från optionsprissättning till konkurslagstiftning. red. Bergström, C., Björk, T.
Hagerud, G.E., A New Non-Linear GARCH Model.
Haksar, A., Environmental Effects of Economywide Policies: Case Studies of Costa Rica and Sri Lanka.
He, C., Statistical Properties of Garch Processes.
Holmgren, M., Datorbaserat kontrollrum inom processindustrin; erfarenheter i ett tidsperspektiv.
Jennergren, P., Tutorial on the McKinsey Model for Valuation of Companies.
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Sjöberg, L., Ramsberg, J., En analys av en samhällsekonomisk bedömning av ändrade säkerhetsföreskrifter rörande heta arbeten.
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Södergren, B., På väg mot en horisontell organisation? Erfarenheter från näringslivet av decentralisering och därefter.
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Åhlström, P., Sequences in the Profess of Adopting Lean Production.
Åkesson, G., Företagsledning i strategiskt vakuum. Om aktörer och förändringsprocesser.
Åsbrink, S., Nonlinearities and Regime Shifts in Financial Time Series.

1996

Advancing your Business. People and Information Systems in Concert. red. Lundeberg, M., Sundgren, B.
Att föra verksamheten framåt. Människor och informationssystem i samverkan. red. Lundeberg, M., Sundgren, B.
Andersson, P., Concurrence, Transition and Evolution - Perspectives of Industrial Marketing Change Processes.
Andersson, P., The Emergence and Change of Pharmacia Biotech 1959-1995. The Power of the Slow Flow and the Drama of Great Events.
Asplund, M., Essays in Industrial Economics.
Delmar, F., Entrepreneurial Behavior & Business Performance.
Edlund, L., The Marriage Market: How Do You Compare?
Gunnarsson, J., Three Studies of Financial Behavior. Research Report.
Hedborg, A., Studies of Framing, Judgment and Choice.
Holgersson, C., Höök, P., Ledarutveckling för kvinnor - Uppföljning av en satsning på Volvo - Research Report.
Holmberg, C., Stores and Consumers - Two Perspectives on Food Purchasing.
Håkansson, P., Wahlund, R., Varumärken. Från teori till praktik.
Karlsson, A., The Family Business as an Heirloom. Research Report.

Linghag, S., Man är handelsstudent. Research Report.
Molin, J., Essays on Corporate Finance and Governance.
Mägi, A., The French Food Retailing Industry - A Descriptive Study.
Mölleryd, B., Så byggdes en världsindustri - Entreprenörskapets betydelse för svensk mobiltelefoni. Research Report.
Nielsen, S., Omkostningskalkulation for avancerede produktions-omgivelser - en sammenligning af stokastiske og deterministiske omkost-ningskalkulationsmodeller.
Normark, P., Danielsson, L., Larsson, A., Lundblad, P., Kooperativa nyckeltal. Research Report.
Sandin, R., Heterogeneity in Oligopoly: Theories and Tests.
Sandén-Håkansson, U., Från kampanjmål till mediemix - en studie av samarbete mellan annonsörer, reklambyråer och mediebyråer. Research Report.
Stein, J., Söderlund, M., Framgång i arbetet, strategier för att utföra arbetsuppgifterna, arbetsuppgifternas karaktär och utbildningskvalitet. En empirisk studie av civil-ekonomer. Research Report.
Strömberg, P., Thorburn, K., An Empirical Investigation of Swedish Corporations in Liquidation Bankruptcy. Research Report.
Söderlund, M., Och ge oss den nöjda kunden. En studie av kundtillfredsställelse och dess orsaker och effekter. Research Report.
Thodenius, B., Användningen av ledningsinformationssystem i Sverige: Lägesbild 1995. Research Report.
Ulfsdotter, U., Internationalisering för expansion eller hemmamarknadsförsvar? De nordiska marknaderna för fruktyoghurt 1982-1994.
Westelius, A., A Study of Patterns of Communication in Management Accounting and Control Projects.
Wijkström, F., Den svenska ideella sektorn och pengarna. Research Report.
Örtendahl, M., Health and Time - A Problem of Discounting.

1995

Becker, T., Essays on Stochastic Fiscal Policy, Public Debt and Private Consumption.
Blomberg, J., Ordning och kaos i projektsamarbete - en socialfenomenologisk upplösning av en organisationsteoretisk paradox.
Brodin, B., Lundkvist, L., Sjöstrand, S-E., Östman, L., Styrelsearbete i koncerner
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Ekonomisk politik i omvandling. red. Jonung, L.
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Levin, J., Olsson, P., Looking Beyond the Horizon and Other Issues in Company Valuation. Research Report.
Mägi, A., Customer Statisfaction in a Store Performance Framework. Research Report.
Persson, P-G., Modeling the Impact of Sales Promotion on Store Profits.
Roman, L., Institutions in Transition. A Study of Vietnamese Banking.
Sandberg, J., Statistisk metod - dess vetenskapliga hemvist, grundläggande principer och möjligheter inom samhällsvetenskapen. Research Report.
Sandberg, J., How Do We Justify Knowledge Produced by Interpretative Approaches? Research Report.
Schuster, W., Redovisning av konvertibla skuldebrev och konvertibla vinstandelsbevis - klassificering och värdering.
Söderberg, K., Farmartjänsten - Ny kooperation inom lantbruket. Research Report.
Söderqvist, T., Benefit Estimation in the Case of Nonmarket Goods. Four Essays on Reductions of Health Risks Due to Residential Radon Radiation.

Thorén, B., Användning av information vid ekonomisk styrning - månadsrapporter och andra informationskällor.