Norwegian University of Science and Technology
Industrial Ecology Programme

'Productivity 2005'

RESEARCH PLAN
P-2005 INDUSTRIAL ECOLOGY

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Norwegian University of Science and Technology, NTNU.
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PREFACE

The research plan for P2005 Industrial Ecology is part of the industrial ecology preparatory phase; an area of focus within the Norwegian long-term research programme 'Productivity 2005' (P2005). Industrial ecology is a new system-oriented perspective – or a set of strategies and practices – in modern industrial environmental policy. It is also a new multidisciplinary university programme in research and education at the Norwegian University of Science and Technology, NTNU Trondheim. This activity was initiated at NTNU in 1993, and since then three international seminars on industrial ecology have been held in collaboration with the Norwegian Academy of Technological Sciences (NTVA). New student courses are currently being developed, and a group of M.Sc. and PhD students has been established in this field. Furthermore, the first steps have been taken to create an LCA laboratory at NTNU's Department of Product Design, to serve as a national centre of expertise on the use of life-cycle assessment in industrial design and research projects. This has been developed in close collaboration with Norwegian industry and leading universities abroad.

In December 1997, the board of P2005 accepted the introduction of industrial ecology as a new focus area, in addition to the two focus areas already started: integrated product development and enterprises in networks. During 1998, a multidisciplinary group of researchers and professionals in industry has produced a number of articles and a state-of-the-art report on industrial ecology (in Norwegian), as well as this document which provides an outline of the research under P2005 Industrial Ecology during the coming years.

The research in P2005 Industrial Ecology is to take place in close collaboration with industrial partners, i.e. the 'core companies' who are involved in the P2005 programme, and 'case companies' which collaborate on a case basis. This will be accomplished by giving a high degree of attention to 'industrial cases' that focus on practical needs and challenges as experienced in industry according to their longer-term strategies. Such cases will in fact have major impact on the more long-term research activities that are going to be undertaken in the 'core projects' of P2005 Industrial Ecology. These activities will cover issues such as economic efficiency and ecological effectiveness, environmental accounting, eco-design methodologies for products and production systems, waste recycling, extended producer responsibility, LCA methodology, terminology and communication challenges and so on.

Several persons have written this research plan. As editors and main authors of this report, and moderators of the working process, we wish to thank in particular Bernt Saugen (Tomra Systems a.s.a.), Kjersti Kviseth (HÅG a.s.a.) and Tove Spetalen and Monica Hagen (Polimoon A.S.A.) for valuable impulses and their input. P2005 Industrial Ecology as proposed in

this document will involve close to 20 companies altogether, focusing on two core research projects and eight industrial cases. Moreover, research institutes and regional colleges will be involved in the work: Sintef Group, Østfold Research Foundation (STØ), and Ålesund College. Nevertheless, according to recent priorities set by the of P2005 board, this research programme is primarily a strategic measure to enhance the interdisciplinary expertise within NTNU and the working relations between its research groups and the manufacturing industry. We appreciate the many fruitful discussions in meetings of the interdisciplinary reference group of researchers in the project, and the written contributions to this report. The following persons have been involved: Odd A. Asbjørnsen, Ole Jørgen Hanssen, Kristin Wiggum, Jan Hovden, Olav Fagerlid, Erik Solem, Anders Skonhoft, Signe Kjelstrup, Hallvard Svendsen, Stig Larssæther, Kjetil Røine and Helge Brattebø, all from NTNU, as well as Odd Myklebust, Trond Lamvik, Ranveig Kviseth Tinmannsvik, Thomas Dahl, Øivind Hagen and Arne Nesje, all from the Sintef Group.

The aim of this research plan is to explain the proposed research directions in P2005 Industrial Ecology, and to present the industrial and academic partners. However, there is room for change and a review of priorities as the project evolves. This will in part be required so more specific research interests can be inserted, both by industry and academia, following the process of examination and mutual discussions in the industrial cases, and in part so modifications can be made after greater interaction with institutions abroad.

This report is a modification of an earlier version published by Sintef Industrial Management, where Chapter 10 now also shows the success criteria and aims of the project that are confirmed by the Steering committee for P2005.

Trondheim, Norway, June 2000.

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SAMMENDRAG

Denne forskningsplanen i P2005 Industriell økologi (IØK) er utviklet som del av den forberedende fase av satsingsområdet Industriell økologi innen forskningsprogrammet Produktivitet 2005 (P2005). Industriell økologi er et nytt systemorientert perspektiv – eller et sett av strategier og metoder i praksis – i den moderne produktbaserte og kretsløpsorienterte miljøpolitikken. Det er også et nytt multifakultært program for forskning og undervisning ved NTNU. Denne virksomheten ble startet ved NTNU tilbake i 1993, og siden da har det blitt arrangert tre internasjonale seminarer i regi av Norges tekniske vitenskapsakademi (NTVA). Man har startet utviklingen av nye kurs, og en gruppe av hovedfagsstudenter og doktorgradsstipendiater er etablert. Videre har de første skritt blitt tatt for å utvikle et nytt LCA-laboratorium til å være et nasjonalt kompetansesenter i bruk av livssyklusanalyse i industrielle designprosjekter og i forskningsprosjekter. Samlet sett er denne aktiviteten under utvikling i nært samarbeid med ledende utenlandske læresteder og med norske industriselskap, koordinert av NTNU's Program for industriell økologi (IndEcol). Se ellers programmets nettsider www.IndEcol.ntnu.no.

I desember 1997 besluttet programstyret i P2005 å starte satsingsområdet Industriell økologi (IØK), etter modell fra de to andre satsingsområdene Integrert produktutvikling og Bedrifter i nettverk. I løpet av 1998 har en tverrfaglig sammensatt kjernegruppe av forskere og deltakere fra samarbeidende bedrifter i P2005 IØK produsert et sett av tematiske artikler og en State-of-the-Art rapport på feltet. I tillegg har kjernegruppen stått for innspill og drøfting av fremtidige viktige forskningsoppgaver på feltet, noe som har ledet frem til denne forskningsplanen.

Forskningen i P2005 IØK skal gjennomføres i nært samarbeid med industrielle partnere, dvs. kjernebedrifter med en sterk og langsiktig involvering i P2005 og case-bedrifter som samarbeider på case-basis. Det blir i det hele tatt en sterk fokusering på case og industrimedvirkning, sentrert rundt praktiske behov og langsiktige utfordringer slik de oppleves i industrien. Case-problematikk vil således også influere sterkt på den mer langsiktige forskningen som skal utføres som del av kjerneprosjekter i P2005 IØK. Her tar forskningen opp temaer knyttet til økonomisk og økologisk effektivitet, miljøregnskap, øko-design av produkter og produksjon, resirkulering, utvidet produsentansvar, LCA-metodikk, terminologi, kommunikasjon, m.m.

Forskningsplanen er skrevet med bidrag fra en rekke personer. Som redaktører og prosessledere vil vi spesielt takke Bernt Saugen (Tomra Systems a.s.a.), Kjersti Kviseth (HÅG a.s.a.) og Tove Spetalen og Monica Hagen (Polimoon as) for verdifulle innspill underveis i arbeidet. P2005 IØK vil involvere noe under 20 ulike bedrifter, og fokusere sin forskning langs 2 kjerneprosjekter og 8 bedrifts-case. I tillegg til faggrupper ved NTNU vil

samarbeidende forskningsinstitutter og regionale høyskoler delta: Sintef-gruppen, Stiftelsen Østfoldforskning (STØ) og Høgskolen i Ålesund. Likevel vil prosjektets primære målsetning, i henhold til premisser satt av P2005's programstyre, være å bidra til å styrke den tverrfaglige kompetansen ved NTNU og samarbeidet mot norsk vareproduserende industri. Vi setter pris på de mange nyttige diskusjoner vi har hatt i prosjektmøter og i kjernegruppen i løpet av arbeidet så langt, og skriftlige bidrag til denne forskningsplanen. Følgende personer har vært delaktig i dette arbeidet: Odd A.Asbjørnsen, Ole Jørgen Hanssen, Kristin Wiggum, Jan Hovden, Olav Fagerlid, Erik Solem, Anders Skonhoft, Signe Kjelstrup, Hallvard Svendsen, Stig Larssæther, Kjetil Røine og Helge Brattebø, alle fra NTNU, samt Odd Myklebust, Trond Lamvik, Ranveig Kviseth Tinmannsvik, Thomas Dahl, Øivind Hagen og Arne Nesje, alle fra Sintef-gruppen.

Denne forskningsplanen inneholder alle hovedelementene som trengs for å beskrive den foreslåtte forskning som skal utføres i regi av P2005 IØK. Planen beskriver også hvilke fagmiljø og bedrifter som vil være delaktige fra starten av arbeidet. I et så langsiktig og dynamisk prosjekt som dette vil det likevel måtte være rom for fleksibilitet og justeringer med hensyn til prioriteringer etter som prosjektet skrider frem. Dette er dels påkrevet for å gi rom for mer spesifikke forskningsinteresser underveis, både fra forskningssiden og fra bedriftssiden, som resultat av de kommende samarbeidsprosessene i de ulike case, og som resultat av et tettere samarbeid med de ledende fagmiljø i utlandet.

Denne rapporten er en modifisering av en tidligere rapport publisert av Sintef teknologiledelse, der kapittel 10 nå også viser de suksesskriterier og mål for prosjektet som er vedtatt av programstyret for P2005.

Trondheim, juni 2000.

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CONTENTS OF THE RESEARCH PLAN

1. VISION AND MAIN AIMS OF THE RESEARCH PLAN

1.1 Industrial ecology – an introduction

In 1989, industrial ecology was presented to the National Academy of Sciences in the US as a new term, or rather a new paradigm for environmental thinking on industrial environmental behaviour. This term is based on an analogy of industrial systems to natural ecological systems.

The idea of industrial ecology is based upon a straightforward analogy with natural ecological systems. In nature an ecological system operates through a web of connections between organisms whereby nothing that contains available energy or useful material will be lost. Some organisms will evolve with the ability to survive off any waste product that provides available energy or usable material. Ecologists talk of a food web: an interconnection of uses of both organisms and their waste. In an industrial context we may think of this as being the use of products and waste products. The system structure of a natural ecology and the structure of an industrial system, or an economic system, are extremely similar.

In an industrial ecological society, the industry and its products, where energy and materials form metabolic pathways, constitute the core. Resource extraction and waste disposal are within the capacity of the ecosphere. Products are the "organisms" of the industry, each has a function and a life run. Products arise as a response to *human needs.* From there the product is shaped into a design, produced, distributed and used to serve its function - until it is disposed of at the end of its life. However, its material and energy can be reused in other products and processes.

The Journal of Industrial Ecology, established in 1997, addresses a number of related topics: material and energy flows studies ("industrial metabolism"); dematerialization and decarbonization; life-cycle planning, design and assessment; design for the environment; extended producer responsibility ("product stewardship"); eco-industrial parks ("industrial symbiosis"); product-oriented environmental policy; and eco-efficiency.

Since 1996 industrial ecology has been given high priority as a new research field at NTNU, supported by a parallel initiative on sustainable production at Sintef. P2005 Industrial Ecology will be an important part of the efforts to develop these strategic areas of competence.

P2005 Industrial Ecology can be understood as part of an extended productivity concept, where ecological and economical aspects of given systems are to be connected in order to achieve eco-efficient and eco-effective solutions. Our aim is to search for methods and knowledge that hopefully will enable us to combine environmental efficiency and ecological

effectiveness, on the micro and macro scale. Sustainable improvements should be made both on the company and societal level. One of the important research questions within industrial ecology is how to unify these interests that traditionally have been seen as conflicting, by exploring and implementing initiatives where actors collaborate along and across value chains. Such knowledge must stem from systems thinking and system-technical methods which satisfy the needs of the scientific and industrial communities. From industry, an important demand will be to connect environmental improvements and economic profitability in the short-term. However, we believe that companies will not succeed in the long-term if they do not today also pay sufficient attention to opportunities and needs that lie decades ahead. To do this, we need to analyse future needs, set strategies and goals according to these needs, quantify performance and measure progress. This is one of the reasons why a quantification of economic efficiency and ecological effectiveness (from here we shall call the combination of those two terms 'eco-effectiveness') using life-cycle principles is so important. Such quantification, on different levels, must be an important element of P2005 Industrial Ecology. Major methodological challenges are also connected to principles of good practice when implementing industrial ecology in the manufacturing industry to achieve a process of step-by-step progress.

1.2 Vision, challenges and strategic interests

The vision of P2005 Industrial Ecology is clear and indeed challenging when it comes to innovation and successful implementation of industrial ecology principles both in industry and the university:

> "The vision of P2005 Industrial Ecology is to raise NTNU to a world-class research and education level in the sphere of industrial ecology. The activity should be characterised by innovative interdisciplinary approaches, bridging the emerging expertise in technology and the social sciences, and with good relations to other leading universities abroad. The research shall help to form a scientific basis for NTNU's new multidisciplinary study programme in industrial ecology. The overall activity shall be strongly influenced by needs as expressed by the Norwegian manufacturing industry in order to ensure that NTNU can provide candidates, expertise and methodology to industry according to its long-term challenges in this area."

The success of P2005 Industrial Ecology is of course closely linked to the overall challenges industry will face in the coming years. Hence, the

outcome of our research will have to take into account the fact that development of expertise in this area should focus on:

i) The ecological challenges the manufacturing industry will have to deal with when combining a high degree of environmental and resource efficiency and competitiveness in a market – and in a society – where ecological issues (eco-effectiveness) are given more and more attention.
ii) The trade-off between good eco-strategies at the company level and at the macro level, on a short- and long-term basis.
iii) The challenges and the possible environmental benefits resulting from new types of network collaboration, along and across the value chain.
iv) A clarification of new principles and methods for assessing and implementing measures leading to improved life-cycle performance in product and production systems, as well as systems for recycling and producer responsibility.

After working with industrial ecology at NTNU during a five-year period, and after one year of P2005 research, we are now able to pinpoint the strategic interests of the Norwegian manufacturing industry and NTNU.

The strategic interests of the Norwegian manufacturing industry:

- Industry must be able to implement and document eco-efficient solutions in their management systems, and in their production and product development
- Short-term efforts should support long-term strategies in industry, where eco-responsibility and external dialogue help to shape society's development in a sustainable direction
- Environmental issues and eco-investments are becoming important premises for a company's competitiveness in the market
- Methods and solutions to be used have to be in accordance with the company's capacity in practice

The strategic interests of NTNU as a leading university:

- NTNU's strategic efforts in the area are co-ordinated by the Industrial Ecology Programme (IndEcol) – hence, the key is to make P2005 a central measure to strengthen NTNU through IndEcol as a programme, by giving priority to:
  - recruitment (MSc and PhD students) and development of competence (faculty staff)
  - research-based teaching (new IndEcol study programme)
  - interdisciplinary collaboration, particularly bridging expertise in technology and the social sciences

- industrial collaboration (core and case companies) and other external relations
- internationalisation and partnerships with other leading universities

- P2005 Industrial Ecology, despite its broad disciplinary orientation, should be thematically focused, and should be developed on the basis of strict co-ordination between IndEcol's various activities (LCA laboratory, other PhD research projects, the faculty forum and the student forum, teaching and tutoring activities and so on.)

These interests must influence the overall profile and the research elements of P2005 Industrial Ecology. Research objectives and success criteria for evaluation must also take this as a starting point.

1.3 Objectives

The objectives of P2005 Industrial Ecology are given below:

Main objective

- To raise the level of expertise at NTNU, and disseminate knowledge on product, production and recycling systems through research and networking in such a way that the Norwegian manufacturing industry has access to candidates, expertise and methodology that will help companies implement more eco-effective and competitive solutions in such systems.

Targets

- To develop new research-based education on an internationally high level within the new multifaculty Industrial Ecology (IndEcol) study programme at NTNU
- To strengthen the alliances within industrial ecology with leading academic institutions abroad
- To prepare the grounds for an international breakthrough for Norwegian companies on the basis of the activities within P2005 Industrial Ecology
- To help make the concepts of industrial ecology and eco-effectiveness operational in industry in such a way that core companies and case companies can use them in their practice in a credible and measurable way, and to disseminate results of such practice to other companies in the manufacturing industry

During the process of developing our state-of-the-art report, we received input from a wide range of actors, both in academia and industry. This approach resulted in a comprehensive document, where several research challenges have been outlined. We now feel we need to define a more

prioritised research focus, pinpointing what will be the centre of our further activities as specified by this research plan. Within these priorities, we will aspire towards long-term thinking and high quality in line with the intentions behind P2005.

2. STRUCTURE OF THE OVERALL RESEARCH PLAN

In line with the recommendations in the state-of-the-art report, research related to eco-effective solutions in life-cycle product systems is a vital part of P2005 Industrial Ecology. This implies a balance between economic efficiency and ecological effectiveness. Major challenges also remain within theory and methodology development, as well as more practical issues encountered when implementing the principles of industrial ecology in product, production and recycling systems of relevance to the manufacturing industry.

2.1 Overall structure

Bearing this in mind, two core projects have been chosen, with special reference to i) environmentally motivated product and production development, and ii) producer responsibility towards more effective handling of waste reduction, reuse and recycling issues in the material cycle. An important challenge here will be the development of methods for documentation and evaluation of economic and ecological effectiveness as part of product-based environmental policy, with special focus on what are good solutions and practices in relation to product eco-design and materials recycling.

We have also chosen to include two horizontal activities to help the involved actors (as identified in the state-of-the-art report) clarify and make use of common issues such as terminology, LCA methodology, eco-responsible corporate attitudes and more open communication processes in the area of industrial ecology. The national LCA laboratory that has now been established at NTNU as part of the IndEcol programme and with support from the P2005 programme will help facilitate some of these efforts.

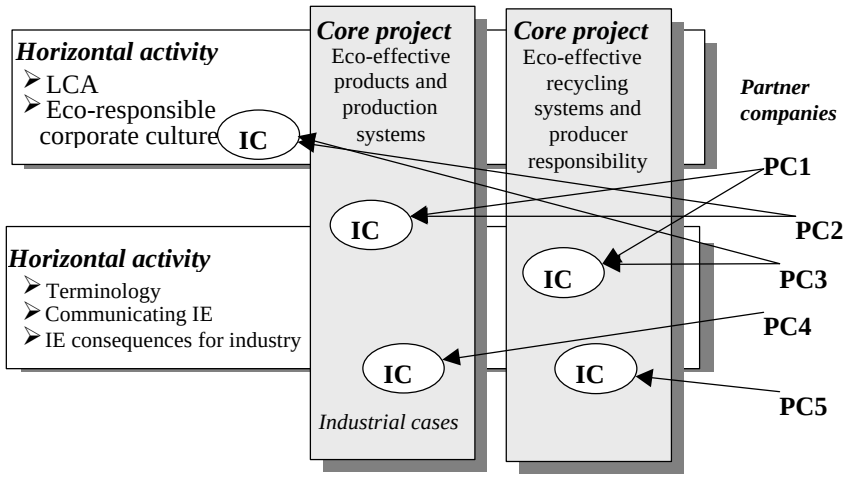

Figure 1. Core projects, horizontal activities, industrial cases (ICs) and partner companies within P2005 Industrial Ecology (IE).

Industrial cases are directly incorporated as part of the core projects. Most of these cases are to be carried out as network projects where two or more industrial companies collaborate. We want to make direct use of the partner companies as research laboratories. At the same time we need to ensure that the actual needs as expressed by companies have a direct and strong impact on the nature of academic research. PhD and Master level students may be useful in such case projects, and these projects may serve as a good basis for proposing and initiating new student research projects. Case projects will of course also be highly beneficial to the teaching and project assignments in the new IndEcol study programme at NTNU. A strong relation to industrial cases is highly preferred in the area of industrial ecology, as leading industrial companies are already paying a great deal of attention to this area, and as industrial ecology research will have to be closely associated with real-life problems and situations.

2.2 Core projects

Figure 1 shows that P2005 Industrial Ecology intends to concentrate on research within two core areas in the coming years, and we call this activity the 'Core projects'. This research will be planned and carried out according to the overall descriptions given in Section 4 (Core project #1) and Section 5 (Core project #2). The two core projects are to combine three main elements:

- The need for scientific production and methodology development in the field of industrial ecology
- The priorities according to needs in the Norwegian manufacturing industry
- The priorities according to the needs of NTNU and collaborating research institutions

In this way P2005 Industrial Ecology will serve both as a strategic measure with a view to making scientific progress, and as a more short-term measure to facilitate re-orientation and the use of new methods in industry itself. The strategic research measures aim at focusing on interdisciplinary and life-cycle oriented aspects related to eco-effective product, production and recycling systems in society.

The core projects aim at improving the understanding and practice of environmental solutions in industry. We have decided to focus on two parts of the product-life-cycle system, namely the supply side (product and production development) and the end-of-life side (product reuse and materials recycling). In practice, these two parts will have to be considered jointly in order to achieve higher environmentally oriented 'productivity', and linked together by the user or consumer phase, which will also have major impact on the other two phases.

Each of the two core projects includes two 'research strategies' to be followed in parallel by undertaking research according to a set of main research questions as outlined in this research plan. Such research questions are formulated in line with the dialogue we have had between the project partners in academia and industry. This is a direct follow-up of the challenges that were focused on in the state-of-the-art report. These research questions generally have a long-term orientation, however, short-term needs and opportunities in industry will also be covered, and the core projects will be shaped to a large degree by the focus and results of the industrial cases. In 1999, which was the first year of research in P2005 Industrial Ecology, most of the budgets were dedicated to activities closely related to the industrial cases.

2.3 Horizontal activities

The horizontal activities (Section 5) involve two research projects on the further development of the LCA laboratory at NTNU and on how companies in the manufacturing industry build 'responsibility' into their organisation and management structures, as well as into their business culture. This research, which constitutes Horizontal activity #1, is to be carried out with a clear allocation of budgets and responsibilities, in accordance with the same principles used in the vertical core projects.

On the other hand, as P2005 Industrial Ecology will involve persons from several companies and research departments and institutions, horizontal communication, meetings and seminars will be needed. To some extent, the contents related to the areas of terminology and communication of industrial ecology and its consequences to Norwegian industry will also need research funds to develop through seminars and meetings. This is what constitutes Horizontal activity #2.

2.4 Industrial cases

A total of eight industrial cases (see Section 6) have been included in the P2005 Industrial Ecology project from the beginning in 1999. These case projects will generally last until the end of 2000. The intention is that this period will be used to maximise industrial input in the shaping of the longer-term research activities. The outcomes of the case activities shall help to clarify and prioritise the future research foci, the scope and the methodologies within each of the two core projects.

To a large extent, the industrial cases are designed as 'network projects', meaning that there is a network of more than one industrial company, and more than one research department involved in a case project. This is a strategic choice, made in order to stimulate synergy among as many project partners as possible, since, after all, many of the research issues that are addressed in P2005 Industrial Ecology are of common interest to the entire group of project partners.

Case 01 Title: Eco-effective value chains in the food industry
Case 02 Title: Environmental indicators and accounting methods in furniture production systems
Case 03 Title: From eco-design to factor 4/10 development in eco -effectiveness
Case 04 Title: Eco-efficiency of beverage container recycling systems
Case 05 Title: Eco-parks as strategy in industrial ecology and local Agenda 21 programmes
Case 06 Title: Principles of good practice towards loop closing
Case 07 Title: Development of information network system of Norwegian LCA databases
Case 08 Title: Eco-responsible companies in manufacturing industry

Each of the industrial cases is described in more detail in Section 6. As can be seen from Sections 5 and 6, two cases (Cases 07 and 08) are not part of the core projects, but are rather part of Horizontal activity #1. The reason for this is that the issues covered in these two cases are relevant to all partners in the overall project.

2.5 Project organisation

P2005 Industrial Ecology will be organised using the following elements:

- A five-member central project working group, headed by the project manager (professor Helge Brattebø, NTNU) and the assistant project manager (Bernt Saugen, Tomra Systems a.s.a.)
- An extended project reference group (all involved key persons with local responsibility)
- Two core projects with a total of four research strategies (1.1, 1.2, 2.1 and 2.2), each with a person in charge of the long-term research activity
- Eight industrial cases, each with a person in charge from the research side and one contact person in industry
- Two horizontal activities, including projects of common interest, as well as communication, meetings, seminars and project management

P2005 Industrial Ecology is not meant to have a very strict hierarchical organisational structure. As much of the project budget as possible is to be allocated to the actual research activity in the core and case projects, and each project has one person responsible for issues related to budgets, tasks, personnel and reporting. Overall accounting and reporting is to be undertaken by the project manager and project staff at NTNU's Industrial Ecology Programme (IndEcol).

The activity will be reported on and co-ordinated by the projectmanager, with help from the assistant project leader and the IndEcol staff. The reference group has been redesigned to have a smaller and more efficient group than we have had during the 1998 preparatory phase. The new extended reference group will meet twice each semester, with one larger annual seminar. Local meetings and seminars within the various sub-projects will also be held. Companies will be invited to attend one extended reference meeting per semester.

The project manager is responsible for co-ordinating all matters and reporting to the Norwegian Research Council and the P2005 board, and will chair the reference group. The assistant project manager will co-chair the reference group, and particularly co-ordinate the industrial interests in the project.

3. CORE PROJECT #1: ECO-EFFECTIVE PRODUCTS AND PRODUCTION SYSTEMS

3.1 Background

As shown in the P2005 Industrial Ecology state-of-the-art report, the product life-cycle oriented approach is the main new focus of both industry and government for dealing with environmental problems. This shift from emphasising point sources to whole cycles of products and materials – and the behaviour of major actors in such cycles – has led to the development of a number of new environmental management methods and tools. These methods naturally need to be based on systems approaches. Life Cycle Assessment (LCA) is an important basis for most of these methods, such as the use of eco-design, environmental performance indicators and evaluation, environmental product declarations, and so on. Most of these methods have now been developed to a level where the most proactive companies use them, and Scandinavian companies have been among the leaders in this development on an international scale. The research challenge is thus first of all to understand patterns and gain experience from application of these tools to learn more about our traditional manufacturing systems and their products, and about fundamental principles and practices in order to implement eco-effective changes. The use of research examples on generic experiences from product types is a good starting point for further research. Another important research subject is how well these methods really work in decision-making processes in companies or public institutions as a tool for integrated supply chain management.

Both international and national research has shown that the simple value chain approach alone is not sufficient to reach a higher level of sustainability of business activities. The industrial ecology concept, with a focus on various types of value chain web structures might be a necessary development stage in the environmental strategies of companies. This value chain web structure might lead to at least two new ways of extending the borders of a company's environmental activities to:

- Multifunctional networks, where several companies work together to identify and implement more eco-effective total solutions for a multifunctional system (e.g. the 'Eco-Effective Office Workplace 2005')
- Eco-park, where companies within a local region collaborate by exchanging (cascading) resources and by-products such as energy, water, materials, waste, transport services, in order to reduce the overall environmental burden on surrounding systems.

These new types of organisational structures are among the most promising approaches to the development of technical systems with a large improvement in eco-effectiveness that might be necessary to reach sustainability in a 30-50 year perspective. Some scientists claim there is a need for 'factor 4 to factor 10' improvements. We know that the rigidity of large-scale infrastructure in society will reduce the freedom to reach such long-term goals. As a similar type of infrastructure is continuously being planned and built in our society, it is important to start a process through which we can acquire a better understanding of the nature of possible actions for factor 10 technical and cultural systems immediately. In the mean time, the same approach might also make it easier to reach a factor 4 improvement, which should be attainable within a shorter time scale.

As P2005 is a research programme focusing on long-term productivity development, especially in the manufacturing industry, the focus points raised above are indeed relevant for such a programme. Other types of more easily achieved results will be dealt with in more traditional applied-research programmes, but should be coordinated with the activities in the P2005 Industrial Ecology programme.

3.2 Main aims of Core project #1

The main aim is to lead a number of Norwegian manufacturing companies far into the process of recognising the need for more radical sustainable business activities, products and processes, and start applying methods to support such a change in design policies. In doing this, we will help the companies make continuous improvements by looking beyond their own system boundaries, and spread general results and experiences to other companies, authorities, non-governmental organisations and students at different levels.

3.3 Research strategies and issues

The research activities in Core project #1 will be undertaken within two main research strategies:

RS 1.1 Eco-effective value chain management in industry
RS 1.2 Factor X development of technical systems

Both activities are described in more detail below, and will be directly connected to industrial cases.

Three general research subjects will be covered with reference to each of the research strategies:

1. Methodologies for quantification of eco-effectiveness with regard to products, companies and networks of companies, and how to use this information in specific industrial cases.
2. Governmental regulations and financial instruments as promoters or barriers to development of eco-effective solutions in product and production systems.
3. Best organisation, organisational learning and new ways of managing eco-effective companies and networks of companies in relation to product and production development.

3.3.1 Research Strategy 1.1: Eco-effective value chains

Person in charge: Professor Annik Magerholm Fet, NTNU Department of Industrial Economy and Technology Management.

This first research strategy will focus on more traditional LCA and eco-design activities within value chains in the first phase of food industries and packaging products. This will be a necessary basis for companies to cover before they can work further with other strategies of this research plan. However, Research Strategy 1.1 will also have a value of its own, as there is potential for significant improvements in eco-effectiveness in each value chain itself.

The main research questions to be studied in RS 1.1 will be:

- How do we integrate environmental aspects in information systems and development processes along a value chain, e.g. between a customer and its suppliers?
- How do we integrate different tools and methods in development processes efficiently, such as Quality Function Deployment (QFD) and similar methods, with Life Cycle Assessment methods?
- What are the requirements for structures and definitions that will help the users focus on the right decision areas, and make the right decisions in the different phases of a development process?
- How do we reduce the effect of asymmetric information between the different actors along a value chain, and other stakeholders relevant to the value chain (financial institutions, authorities etc.)?

This research will be carried out with strong support from industrial cases. One industrial case (Case 01) will concentrate on environmental needs related to the fish industry, vegetable products and meat products, with the

companies Norske Potetindustrier, West Fish - Aarsæther AS, and possibly also Norsk Kjøtt, as industrial partners. Attention will be paid to total use of biological resources, energy in production and distribution, transport and logistics, packaging and consumer behaviour. The next case (Case 02) focuses on the use of environmental indicators and accounting methods in furniture production systems, where the aim is to arrive at practical accounting systems and indicators as part of an industrial collaboration with local communities and to establish a code of practice for furniture companies.

3.3.2 Research strategy 1.2: Factor X development

Person in charge: Associate. Prof. II Ole Jørgen Hanssen, NTNU Dep. Product Design

The research activities within this strategy will focus on how companies and networks of companies can improve the eco-effectiveness of technical systems by factors 4 to 10 to reach higher levels of sustainability. Such improvements are in most cases not achievable on a basis of single products fulfilling simple user functions (e.g. an office chair). Hence, an important basis of the strategy is to focus on network projects between companies within the scope of multifunctional systems (e.g. an office workplace).

The main research questions to be studied within RS 1.2 will be:

- How do we measure eco-effectiveness in multifunctional systems as a basis for problem specification, identification of options for improvements, prioritising between options and tracking the success of implementation of the options?
- How do we initiate and carry out processes related to factor X development in a network of companies?
- How do we manage these processes within companies and between companies?
- Will it be necessary or efficient to develop radical new types of organisations for such multifunctional systems?
- What are the most effective options in factor 10 solutions (e.g. dematerialization, from product to service, new infrastructures, local based resources, closed loops, optimum product life times, etc.)?

Research will be carried out in networks between companies. In 1999 a general case network project was started with the aim of developing a state-of-the-art report for factor X improvements, as well as development of methods for further implementation in more specific networks. This first network project will be followed up with a number of network projects

related to specific multifunctional systems. The basis for these projects will be the involvement of one or more companies that will be responsible for leading the process of factor X networks.

Moreover, more general research projects will be carried out in multidisciplinary research teams, covering the more general methodology questions.

In 1999, an industrial case network project (Case 03) was established, focusing on factor X development in companies and with a case network between HÅG, Polimoon and Norcem. After this initial phase with a main focus on methodology development and testing, two to three new case projects will be established. The intention is that these cases will centre on multifunctional products such as 'Eco-effective Offices 2005', 'Eco-effective Kitchens 2005', and so on.

4. CORE PROJECT #2: ECO-EFFECTIVE RECYCLING SYSTEMS AND PRODUCER RESPONSIBILITY

4.1 Background

While Core project #1 addresses design and collaborative solutions more precisely related to the production and consumer phases of value chains, Core project #2 will focus on challenges related to recycling systems and the implementation of Extended Producer Responsibility (EPR) in manufacturing industry. EPR is a new governmental instrument, and an important part of modern environmental policy programmes, where the aim is to facilitate more efficient recycling systems in society by addressing the responsibility of producers for end-of-life products. EPR is to be understood as a collective physical and economic responsibility of producers and importers within a given sector, e.g. the industry producing plastic polymer packaging products. The industrial actors are given responsibility for end-of-life product take-back, either by means of governmental regulation or by covenants. The recycling systems for product take-back are rather complex, involving several types of actors, products and materials. In general, such systems should involve subsystems for source separation, collection, transportation, processing and development of robust markets for recycled materials.

Obviously, critical parts of any recycling system will be:

i) Quality and availability of end-of-life products and the input of waste materials in the recycling system
ii) Efficiency of the collection, transportation and processing parts of the system
iii) Demand for secondary (or recycled) materials, and quality and cost criteria on the demand side, in order to substitute for use of primary (or virgin) materials

Any product reuse or recycling system will have to be examined and understood as an integrated part of the product life cycle, in which consumer and market demands traditionally dominate all production and product development strategies. Product reuse and recycling systems must of necessity also be integrated parts of the overall end-of-life waste management systems. An economically efficient and ecologically effective

reuse and recycling system will therefore have to take into full consideration both major economic and ecological criteria of production systems, as well as those of waste treatment and disposal systems. Thus, two more critical parts of a recycling system must be added to the three mentioned above:

iv) Resource efficiency (or resource productivity) of the recycling system, with respect to reduced demand for primary materials and energy resources
v) Potential ecological impact of the recycling system with respect to reduced emissions to air, water and soil recipients.

Simply stated, a recycling system's primary objective is to recover the material and energy embedded value of end-of-life products with a minimum of extra resource requirements. The economic efficiency of a recycling system tells us the degree to which the system creates an added economic value per unit of materials flow in the system. In Core project #2, we may carry out the research on the basis of industrial needs and some basic hypotheses. The following statements indicate our hypotheses in this research. Economic efficiency will depend on the recycling ratio in the system, as specific collection and processing costs are likely to decrease at low recycling ratios as there is high investment in infrastructure and low recycling volumes. Similarly, such specific costs are likely to increase at high recycling ratios, as the materials of end-of-life products become less easily available and less pure in quality. The ecological effectiveness of today's recycling systems will most likely increase with higher recovery ratios as the current (external) damage to resources and recipients is high and most of the materials today flow linearly from resources and end up as waste (lost resources) discharged to recipients. However, with higher and higher recovery ratios, energy demand for collection, transportation and processing of secondary materials will increase and possibly dominate positive gains related to resources and recipients. Hence, it should not be possible to combine high materials, recycling ratios and eco-efficient energy conversion in such systems, unless the recycling systems are fully driven by clean and renewable energy sources. Finally, we believe that decentralised solutions in recycling systems in general are to be preferred over largely centralised (at the national level) solutions, as transportation parameters will dominate the large centralised systems.

If these patterns of eco-effectiveness in recycling systems are correct, optimum levels of recovery ratio will be found in any recycling system. These patterns may be examined by combining system theory, economic and thermodynamic theory, ecological performance theory, and empirical data from different types of recycling systems. Hopefully, answers of value to actors involved in complex recycling systems may be given by assessing selected cost, energy and LCA-related parameters, in relation to simplified models of real-life recycling systems and future scenarios for changes in key

parameters in such systems. A starting point could be to apply such methodology on recycling systems for beverage containers, focusing on the key interests of Tomra Systems a.s.a.

The research will also take a more practical approach, with a short-term perspective. P2005 Industrial Ecology shall help clarify principles of good practice for companies in the manufacturing industry, as well as other key actors in local and national recycling systems. Such efforts would be of interest to several companies, such as Polimoon and HÅG, as well as companies in the electric and electronic products sector, where a new producer responsibility regulation is to start.

4.2 Main aims of Core project #2

The main aims of the research in this core project are to improve the expertise Norwegian manufacturing companies have concerning ways of increasing their contributions to economic efficiency and the ecological effectiveness of recycling systems in society. First, such competence should be based on a better understanding of how to quantify, measure and evaluate eco-effectiveness in selected recycling systems. Second, such an evaluation should help clarify critical and operational indicators of eco-effectiveness, as well as principles of good practice to be applied by companies in the short and long term.

4.3 Research strategies and issues

The research activities within Core project #2 will be carried out within three main research strategies:

RS 2.1 Evaluation of eco-effectiveness in recycling systems
RS 2.2 Principles of good practice in local and national recycling systems

The two research activities are described in more detail below, and will be directly connected to industrial cases.

There will be three general research subjects to be covered with relation to each of the research strategies:

1. Methodologies for quantification of eco-effectiveness related to economic and ecological impacts of given recycling systems or solutions, and how to use this information in specific case projects.
2. Governmental regulations and financial instruments as promoters of or barriers to development of eco-effective solutions in recycling systems.

3. Best organisation, organisational learning and new ways of managing eco-effective companies and networks in relation to recycling systems.

4.3.1 Research strategy 2.1: Evaluation of eco-effectiveness in recycling systems

Person in charge: Professor Helge Brattebø, NTNU Dept. Hydraulic and Environmental Engineering/NTNU Industrial Ecology Programme.

Research activities within this strategy will focus on how to measure and evaluate eco-effectiveness in specific recycling systems. As part of such an activity economic efficiency will also be measured and evaluated, as this is a vital parameter to be included in the overall eco-effectiveness evaluation.

The main reason why we wish to emphasise this research strategy is that we believe that systematic modelling of recycling systems, and their eco-quality parameters, will give a much better understanding of the system and its dynamic performance. Hopefully, this will produce better knowledge with respect to how parameters influence the economic and ecological qualities of recycling systems, and how this is linked to key system variables such as mass throughput, recovery ratio, energy prices, transportation costs, waste disposal costs, quality criteria for reprocessed (or secondary) materials and so on.

The main research questions to be studied within RS 2.1 will be:

- How do we apply the concepts of 'economic efficiency', 'eco-efficiency' and 'eco-effectiveness' on recycling systems?
- How do we determine functional units and system borders when applying LCA and LCC tools in assessing recycling systems?
- How may a generic quantitative model for recycling systems help develop a dynamic understanding of such systems, and how may generic models be useful to specific recycling systems?
- How would such models be impacted by changes in key parameters, according to future scenarios for policy related to energy, resources and recipients?
- How do we use simple and operative environmental and economic indicators in modelling and assessing recycling systems?
- How do we value market demand and consumer participation in recycling systems?

The industrial case (Case 04) will dominate this research strategy in the first years so that an empirical approach has been chosen in order to make the research directly relevant to practical needs. The research is particularly

relevant to the interests of Tomra, but both HÅG and Polimoon have expressed interests in this as well. Another company that could have potential interest in this area is Plastretur, as it is to co-ordinate recycling activities for plastic materials in Norway. Future research activities will be more precisely formulated by a multidisciplinary research team, including company staff, according to initial clarifications on the questions given above.

4.3.2 Research strategy 2.2: Principles of good practice in local and national recycling systems

Person in charge: Professor Helge Brattebø, NTNU Dept. Hydraulic and Environmental Engineering/NTNU Industrial Ecology Programme.

The research activities within this strategy are focused directly on good practice in recycling systems. However, as both technical and organisational solutions may be very different in different recycling systems, it is not a fruitful strategy to focus on detailed solutions per se. A better strategy will be to try and reveal more general 'principles of good practice' in such systems.

Recycling systems may be implemented on the local, regional and national scale. On the local scale, recycling is strongly influenced by industrial and municipal source separation, and direct use of separated material or energy resources as part of the local management option for wastes and by-products. On the national scale, recycling systems are now being developed as a consequence of the Extended Producer Responsibility (EPR) concept. EPR means that all producers and importers of materials in a given manufacturing industry will have to be members of a national recycling structure, or prove that they can offer a separate system by themselves.

An interesting recycling option for industry on the local scale is 'eco-park' development, where industrial facilities enter a local network to collaborate on the use of each other's useful wastes and by-products elsewhere in the industrial network or in municipal systems for heat/energy production. An eco-park is defined as a network of industrial companies and value chains with a high level of exchange of materials, energy flows, waste flows, water resources, service resources and so on. Such eco-parks have been in operation, for instance, in the Kalundborg area in Denmark for more than 25 years, with large industrial plants such as an oil refinery, a pharmaceutical company and so on. This area was first developed without a clear Industrial ecology strategy. However, in recent years the companies in the Kalundborg area have worked systematically to improve their total network efficiency. In the Netherlands, an eco-park initiative has recently

been taken in the Rotterdam Port area. In Norway, Borregaard Industries Ltd. is a good example of an eco-park. This large industrial area in Sarpsborg has a large number of plants producing cellulose, lignin, vanillin, sulfur acid, ethanol, fine chemicals and more, all based on raw materials from forestry. Another approach to eco-parks is collaboration among more distributed plants, where resources are exchanged over larger areas, however, still within a rather condensed region. Such "virtual eco-parks" may be applicable to material recycling within and between industrial sectors.

The main research questions on eco-park development (in close collaboration with Ole Jørgen Hanssen) to be studied within RS 2.2 will be:

- What are good methods for quantification of eco-effectiveness in any eco-park structures in Norway?
- What are appropriate methods for a material flow analysis, in order to identify opportunities for network structures and exchange of recycling in local systems?
- What principles could be used to combine business systems through value networks with eco-park initiatives?
- How could similar eco-park network ideas be developed in less concentrated areas?
- How could public authorities (on the national, regional and local level) promote eco-parks, with particular emphasis on local Agenda 21 planning processes.

An industrial case (Case 05) will be established on eco-parks in Østfold. Peterson-gruppen, Borregaard Industries, Kronos Titan, Glomma Papp, Unger and Norske Skog Saugbrugsforeningen will be participating in this first project. This will be a common network project around a specific study area, such as the Øra industrial area. Later on, this case project may be followed by projects in the Øra industrial and harbour area in Fredrikstad, as well as two to three other areas.

Modern recycling systems on the national scale are often based on agreements between government and the packaging products industry, and such regulation strongly influences companies such as Polimoon and Plastretur AS, where an EPR regulation for packaging products was already in place in 1996. A new EPR regulation for electric and electronic waste came into force as of 1 July 1999 and this will have an effect on many companies in the electronic and electric products sector. Hence, research on good principles for EPR implementation will be of relevance to both recycling companies and traditional companies in the manufacturing industry in the packaging and electronic/electric product sectors. Furthermore, companies in other branches of the Norwegian manufacturing industry, such as HÅG and Tomra, are also expressing the need for more

knowledge on principles of good practice in relation to producer responsibility and design for recycling.

The main research questions related to producer responsibility (in close collaboration with Sigurd Støren) to be studied within RS 2.2 will be:

- What are principles of good practice with respect to robust recovery and cost performance over varying recovery ratios, varying input material quality and varying criteria for quality of secondary materials?
- What are principles of good practice if a company is proactively engaged in 'double-loop' and 'close-the-loop' design and management initiatives?
- What factors make it attractive to recycle materials from both a company and societal perspective?
- How may recycling principles have a more active effect on industrial product eco-design strategies?
- What are good principles for communicating good practice in relation to recycling and extended producer responsibility?

The research has been specified in more detail during 1999, in collaboration between academic and company representatives in a joint project group. An industrial case (Case 06) dominated the research focus in 1999, based on contributions from Polimoon, HÅG, Tomra and Plastretur. This case could be expanded to also involve partners from the electronic and electric products sector at later stages.

5. HORIZONTAL ACTIVITIES

5.1 Horizontal research projects between the core projects

Several common issues will be of interest to all research departments and companies involved in P2005 Industrial Ecology. The understanding of such issues may be enhanced during prepared discussions at plenary meetings, where all actors involved in Core projects #1 and #2 will be invited. On the other hand, the development of certain issues of common interest will require systematically planned and performed research over time, more or less in the same way as the research activity within the two core projects. Such joint research will of course have to be carefully moderated over time, and may involve smaller researcher groups as well as industrial cases.

As a follow-up of some of the recommendations in the P2005 Industrial Ecology 'state-of-the-art' report, and later discussions, it has been decided to propose two horizontal research projects (HRPs), which will be part of horizontal activities #1 and #2 in the overall project structure, see Figure 1 on page 7:

HRP 01: LCA laboratory at NTNU
HRP 02: Eco-responsible corporate cultures in Norwegian manufacturing industry

5.1.1 LCA laboratory at NTNU

The LCA laboratory at NTNU is an important part of the development of activities within Industrial Ecology and Life Cycle Assessment methodology. The laboratory is situated at the Department of Product Design, but the aim of the centre is to support all the university's departments. The LCA laboratory is manned by an associate Professor (20% position) and a research assistant (67% position).

The aim of the LCA laboratory is to help develop LCA studies and life-cycle approach in all disciplinary studies at the university, and to promote the concept in Norwegian society. The LCA laboratory will also help to increase expertise and knowledge in LCA methodology and applications at NTNU by offering courses on different levels. In 1998, guest lectures were given in existing environmental courses at the university. Several masters theses are also being written with support from the LCA laboratory. In 1999, new courses focusing on different types of LCA applications have been developed, as well as an LCA expert course.

The activities at the LCA laboratory have been developed in collaboration with the Østfold Research Foundation and major Norwegian industrial companies. In the next three years, focus will be on

methodological questions, development of LCA information network systems (LCA databases) and experiences with LCA in different applications. The main focus will be on development of educational activities and basic research.

To be able to develop a sustainable LCA centre at NTNU, it is necessary to raise our human resources above the present level. In a three-year perspective, it is important to have a PhD student associated with the LCA Laboratory, in addition to the existing associate professor and the research assistant posts. Student assistants may supervise other students' work in lower-level courses. Furthermore, more capacity is needed for the LCA information network system. Some of the resources could be financed through the P-2005 research programme, whereas the rest of the financial support should come from the new multidisciplinary curriculum in industrial ecology at NTNU, which started in 1999.

The LCA laboratory will participate in a network of similar research centres in the Nordic region. A specific case project in P-2005 has been taken from the LCA information network project (Case 07). This project involves industrial companies such as Hydro Aluminium, Hydro Petrokjemi, Norske Skog and Statoil, as well as a collaboration with similar LCA expertise centres in Chalmers University of Technology (Gothenburg) and the Danish Technical University (Copenhagen).

5.1.2 Eco-responsible corporate cultures in the Norwegian manufacturing industry

The current trend in industry, as stated in the 'state-of-the-art' report, is towards a product- and market-oriented environmental policy, where the market and producers themselves are expected to make environmental improvements. When governments as representatives for society's interests delegate such challenges to actors who traditionally have been operating in accordance with more narrow cost-benefit criteria, this gives rise to new opportunities in relation to the responsibility for collective environmental goods in society.

The specific research issues related to such opportunities will be developed in collaboration with industrial companies involved in P2005. The main research focus will be on the changing situations within the environmental domain, and how one acts to manage and implement responsibility and environmental consciousness within the company's organisation and management culture. Several thematic orientations could be of interest. Below some major themes are indicated. The research project will concentrate on some of these, according to more detailed discussions with the companies involved:

Issues related to a company's external relations
- Governmental strategies and transfer of responsibility
- Different national and cultural perceptions on responsibility
- Conscious consumers with a focus on the industry-consumer relation

Issues related to a company's internal relations
- Environmental management systems
- Organisational culture, organisational learning and change processes

This research activity will be directed at companies with varying approaches to the handling of environmental problems, both as individual companies and in collaboration with others. It could also be of interest to perform an international comparative study on producer responsibility and different governmental strategies.

In 1999 an industrial case (Case 08) was started as part of the HRP 01 activity. The companies to take part in this case project have not yet been selected. The case project will secure a user-oriented (i.e. industrial-oriented) approach to HRP 01. After 1999, the research related to this horizontal project should increase in volume, as this is a very good opportunity to bring a better balance between technological and social-science research topics into the overall P2005 Industrial Ecology project.

5.2 Activities associated with project meetings and seminars

Project meetings and seminars will be held at different levels in P2005 Industrial Ecology. The plan is to arrange one three-day seminar each year, involving all partners actively involved in the programme. This could be done in connection with other central P2005 meetings, and parts of the three-day seminar will be in parallel core project sessions. These seminars will serve as excellent opportunities for the presentation and discussion of elements related to all the horizontal activities.

In addition to the two horizontal research projects (HRP 01 and 02) on LCA laboratory and eco-responsible corporate cultures, annual three-day seminars may address other issues of common interest:

- Terminology in the area of industrial ecology
- Communicating industrial ecology opportunities to the society at large
- The overall consequences of industrial ecology for Norwegian industry

As the state-of-the-art report demonstrated, terminology in the area of industrial ecology is still not well developed. Hence, we recommended including a smaller terminology sub-project as part of the horizontal activity, starting the sub-project in 1999,dependent on the availability of funds.

Addressing these issues is a follow-up of observations expressed in the P2005 Industrial Ecology 'state-of-the-art' report. However, these issues will not be dealt with as research projects similar to the others, rather they will be covered by presentations and prepared discussions in sessions at the annual seminars.

Other meetings will mainly take place within the different project groups of the horizontal activities and the individual core projects. In 1999/2000 this will particularly be centred on the industrial cases. In order to maximise the project effectiveness towards the stated research objectives, we feel it is necessary to also concentrate the meetings along such lines. The number of meetings should be kept to a minimum here as well in order to promote productive research work. As a substitute for some meetings and flight travel, we will try to implement a professional electronic communication platform, using e-mail, the Internet and video conferencing as part of the central Intranet/Internet pages of P2005. Much of the research time should be spent actually working inside the case companies.

A new P2005 Industrial Ecology extended reference group will be appointed to meet twice a semester, where one meeting will have greater attendance from industry.

6. INDUSTRIAL CASES

Key information on the different industrial cases is given in the forms on the following pages. We have to point out that most of these cases are outlined as network projects with more than one company involved. This has been done because we feel there are actually several overlapping research interests between the different companies. Hence, it would be reasonable to try and stimulate synergy among the companies when dealing with industrial cases, particularly in the first phase of the research programme.

As the cases mostly deal with 1999/2000 only, follow-up research activities and case orientation for the following years will have to be developed and agreed upon during this first phase. We define Phase 1 of P2005 Industrial Ecology to be the period April 1999 – December 2000, during which each of the industrial cases will have to have a separate report. At the end of 1999 an overall and shorter intermediate report was submitted for each of the industrial cases.

It is important to note that right from the inception of P2005 Industrial Ecology a great deal of attention has been given to industrial cases. Such cases in fact account for a prevalent part of the funds the Norwegian Research Council has made available through P2005 Industrial Ecology in Phase 1. In future years a larger part of the funds will be used for long-term research issues in this area when a foundation has been formed through the industrial cases in Phase 1.

A tentative allocation of budgets (P2005 funds and industrial contribution in kind) is shown in the Case 01-08 tables below. We must underline the tentative nature of these allocations as no final decisions on the budget totals for P2005, and other activities, has been reached. This is more an indication of the overall volume and allocation of budgets. The budgets for 1999 were revised in March 1999 to take into account the new administrative structure of P2005, under which it became a more decentralised research programme, as well as initial obligations from1998 that were transferred to the beginning of 1999 when this Research Plan was finalised.

West Fish – Aarsæther AS		
Case 01: Eco-effective value chains in the food industry		
Case project description The food company West Fish – Aarsæther AS uses different raw materials in their production processes and has a different range of products. In this case project, we want to study the material flow through the plants and production units, including by-product and residual-product handling. We are also studying how to reduce packaging consumption through the production line. A large amount of packaging used when packing semi-finished and finished products must be handled according to environment-friendly principles. In this case we have to consider the problem in connection with disposable versus multithread packaging. It is also necessary to study the handling of by and residual products through the whole manufacturing process to consider how to optimise and lower the packaging flow. The company also packs their products in different packaging for different markets. West Fish – Aarsæther AS faces challenges with their residual-product handling. It is important to control the raw material with a special quality to the right process line to lower the amount of residual products. An "eco-efficient food company" must also be defined with respect to measurement and documentation. This is then followed by an ecological analysis of one product from each of the companies, for instance blocks of frozen fish. We are going to use an Input-Output-analysis or an equivalent method for the LCC analysis and the LCA analysis, where economy and ecology are integrated in line with the definition of eco-efficiency. Finally, we want to find a method to integrate the environmental aspects in information systems and production processes along the process lines.		
Deliverables 1999/2000 ➢ Evaluation of an eco-efficient food industry: with focus on raw material input, packaging, distribution and process flow in general ➢ Packaging evaluation case related to West Fish – Aarsæther ➢ Method for integration of quality, economy and ecology aspects for food industry related to eco-efficient definition in information systems and production processes along the value chain ➢ Student projects and theses on methodology for eco-efficiency in food industry ➢ Methodological description for future case network projects		
Relevance to Core Project The case project will be an essential part of the further development of Core project #1, and will be the basis for development of future case orientation in 2000-2002.		
Person in charge at the companies West Fish – Aarsæther AS: Oddvar Skarbø	**Person in charge at P2005:** Siv.ing. Odd Myklebust, Sintef	
Time schedule: Starts 1March 1999 Ends 31December 2000	**Budget:** NOK 300 000 in 1999	
	P2005: NOK 150 000 in 1999	**Companies:** NOK 150 000 in 1999

Table 1: Summary of Industrial Case # 01

<table>
<tr><th colspan="3">Stordal Møbler AS, Hove Møbler AS, Modi Scandinavia AS,
Helland Møbler AS</th></tr>
<tr><td colspan="3">Case 02: Environmental indicators and accounting methods in furniture production systems</td></tr>
<tr><td colspan="3">Case project description
Stordal Møbler AS, Hove Møbler AS, Modi Scandinavia AS, and Helland Møbler AS are furniture producers located in the community of Stordal in the region of Møre and Romsdal. These companies have been working more or less systematically with projects that focus on the environmental performance of their production processes and their products. However, they lack a set of environmental performance indicators that document their performance in a systematic and comparable way.
This project has the following objectives:
Establish practical environmental accounting systems within each company
Select a set of appropriate environmental performance indicators
Communicate their environmental performance to interested parties and to the local authorities
Establish a code of practice for furniture companies
This project will run parallel with another project where the local authorities (the municipality of Stordal) will acquire competence in environmental accounting systems within companies and the municipality. The outcomes from the case project will therefore be evaluated as an important input to the development of the local authorities' environmental accounting systems and their relevance for industrial companies. The project will contribute to the process of local Agenda 21 and improve production processes and products within the participating companies.
The experience from this project will be valuable for the content in courses on environmental management delivered by the Department of Industrial Economy and Technology Management (IØT) at NTNU.</td></tr>
<tr><td colspan="3">Deliverables 1999/2000
➢ Guidelines for environmental accounting systems in the furniture industry, hereunder a code of practice to establish environmental performance indicators for furniture and furniture production
➢ A set of environmental performance indicators for the furniture industry used to communicate the companies' environmental performances in annual environmental reports
➢ Exemplification and recommendation for course content in environmental management systems for industrial ecology students and other students from IØT.
➢ Project plan for new cases.
➢ Student projects and theses on methodology for communicating environmental performance by means of environmental performance indicators in a local Agenda 21 perspective.</td></tr>
<tr><td colspan="3">Relevance to Core Project
The case project will be an essential part of the further development of Core project #1, and will be the basis for development of future case orientation in 2000-2002.</td></tr>
<tr><td>Person in charge in companies
Stordal Møbler AS: Magnar Skjellum</td><td colspan="2">Person in charge P2005:
Professor Annik Magerholm Fet, NTNU</td></tr>
<tr><td>Time schedule:
Starts 01March1999
Ends 31December 2000</td><td colspan="2">Budget:
NOK 175 000 in 1999</td></tr>
<tr><td></td><td>P2005:
NOK 75 000 in 1999</td><td>Companies:
NOK 100 000 in 1999</td></tr>
</table>

Table 3: Summary of Industrial Case # 02

HÅG a.s.a., Polimoon AS and Norcem a.s.a.		
Case 03: From eco-design to factor 4/10 development in eco-effectiveness		
Case project description HÅG, Dyno and Norcem are companies that have carried out LCA projects for several of their own products, and they have used the information from these analyses to improve their own products and processes. LCA has been integrated in their product development, they have developed Environmental Performance Indicators, and they are now in the process of developing Environmental Product Declarations. The three companies have very different product types and processes, from very short-lived packaging products to medium and long-lived products (office chairs and concrete constructions). In this case network project, the three companies will contribute to the development of methods for factor 4/10 programmes within companies and within a network of companies. Experiences of how such programmes are implemented in companies and networks of companies will be evaluated, keeping an open mind with respect to new ways of organising business activities in the industry. Scenario techniques for identification of long-term changes in consumer attitudes and in the priority of environmental problems will be considered as part of a radical strategy development. The need for changes in governmental policies and measures taken to promote factor 4/10 development will be evaluated. An important basis for the work will be LCA studies of existing products from the participating companies, and generalisation of the environmental profile on the product type level. In 1999/2000 several student projects will be carried out to depict factor X solutions related to the business areas of the participating companies.		
Deliverables 1999/2000 ➢ Report and paper on state-of-the-art for factor 4/10 experiences internationally ➢ Methodological description for case network projects ➢ Student projects and theses on factor X solutions ➢ Project plan for new cases on factor 4/10 development ➢ Two theses/projects at NTNU		
Relevance to Core Project The case project will be an essential part of the further development of Core project #1, and will be the basis for development of future case orientation in 1999-2001.		
Person in charge in the companies: Environmental manager Kjersti Kviseth, HÅG	**Person in charge P2005:** Dr. techn. Ole Jørgen Hanssen	
Time schedule: Starts 01March 1999 Ends 31 December 2000	**Budget:** NOK 350 000 in 1999	
	P2005: NOK 150 000 in 1999	**Companies:** NOK 200 000 in 1999

Table 4: Summary of Industrial Case # 03

Tomra Systems a.s.a., Polimoon AS		
Case 04: Eco-efficiency of beverage container recycling systems		
Case project description Going from linear to closed-loop product flows is believed to be important in creating sustainability. Tomra Systems a.s.a. sees the need to increase expertise in systems and eco-efficiency analyses. This is in line with interests Polimoon AS has, including interest in the design of closed loops. Plastretur AS, which is developing and co-ordinating national systems for recycling of plastic polymer materials, is also a company with a high potential for participation in this case. The objective of this study is to acquire scientific knowledge of the eco-efficiencies of different recycling solutions for beverage containers. The aim is to systematically accumulate knowledge that the involved companies, as well as others, can use to ensure that more eco-efficient solutions are provided on an ongoing basis. This way the demand for external resource inputs for recycling systems may be reduced. This case project will use LCA and input/output methodology to analyse the full product cycle of beverage packaging. Special attention will be given to the recovery part of the system. PET one-way bottles and aluminium cans will be the focus of this project, but the goal is to develop generic models that also can be applied to other packaging materials. Earlier research has shown that material recycling and reuse of products is important not only for waste minimisation but also to improve the overall environmental effectiveness of a packaging system for beverage distribution. However, there are still uncertainties related to key system variables such as recycling ratio, recovery quality, energy use, transportation costs, waste disposal costs, consumer participation costs, etc. More research is needed to identify the best ways of organising these activities under different regional conditions, both nationally and internationally.		
Deliverables 1999/2000 ➢ Report and paper on state-of-the-art for evaluation of eco-effectiveness in recycling systems ➢ Report on eco-efficiency of beverage container recycling systems in connection with Tomra ➢ Methodological description for future case research ➢ Student projects and theses on methodology for eco-effectiveness in recycling systems ➢ Project plan for a future case on evaluation of recycling systems		
Relevance to Core Projects The case project will be an essential part of the further development of Core project #2, and will be the basis for development of future case orientation in 2000-2002.		
Person in charge in companies: Bernt Saugen, Tomra Systems a.s.a.	**Person in charge P2005** Professor Helge Brattebø	
Time schedule: Starts: 01March 1999 Ends: 31December 2000	**Budget:** NOK 350 000 in 1999	
	P2005: NOK 150 000 in 1999	**Companies:** NOK 200 000 in 1999

Table 5: Summary of Industrial Case # 04

M. Peterson & Søn, Borregaard Industries Ltd., Norsk Skog Saugbrugs AS, Unger Fabrikker AS, Kronos Titan AS, Glomma Papp AS		
Case 05: Eco-parks as strategy in industrial ecology and local Agenda 21 programmes		
Case project description Eco-parks are clusters of geographically concentrated production plants which function as networks with a high degree of exchange of materials, energy and other resources. The network structure has its origin from natural ecological systems, where webs of species and food chains are an important basis for effective resource utilisation. In Østfold, such an integrated network of production plants has been developed at Borregaard Industries in Sarpsborg, based on raw materials from the forest. Similar developments might have large potential at the Øra industrial area in Fredrikstad, and within less concentrated areas around Peterson Linerboard in Moss and Saugebrugsforeningen in Halden. In this case project, the companies will contribute to the development of methods on how to implement eco-parks as an industrial-ecology strategy in practice. Experiences from other similar projects in Europe and the USA will be evaluated with respect to quantification of eco-effectiveness, organisation of networks between companies, and measures taken to improve eco-effectiveness in network structures. The need for changes in organisational structures within and between companies will be evaluated, as well as the need for changes in policies and regulations by local, regional and national authorities. In 1999/2000 case projects will be carried out in the Borregaard industrial area in Sarpsborg and the Øra industrial park in Fredrikstad. Student projects will be carried out to gather data and develop mass and energy flow analyses of the areas, and to arrive at specific solutions for the further development of the eco-park concept.		
Deliverables 1999/2000 ➢ Report and paper on state-of-the art for eco-park as an industrial ecology strategy, and with an assessment of the Borregaard Industry area in Sarpsborg and the Øra Industry area in Fredrikstad ➢ Methodological description of case projects between industrial companies to develop eco-parks under different geographical boundaries ➢ Project plan for later cases within different geographical conditions and within/between industrial sectors ➢ Two theses/projects at NTNU/STØ		
Relevance to Core Project The case project will be an essential part of the further development of Core project #1, and will be the basis for development of future case orientation in 2000-2001.		
Person in charge in company: Per-Arne Syrrist, Manager Health, Environment and Safety, Peterson group	**Person in charge P2005:** Dr.techn. Ole Jørgen Hanssen	
Time schedule: Starts: 01March 1999 Ends: 31 December 2001	**Budget:** NOK 350 000 in 1999	
	P2005: NOK 150 000 in 1999	**Companies:** NOK 200 000 in 1999

Table 6: Summary of Industrial Case # 05

Polimoon AS, HÅG a.s.a., Tomra Systems a.s.a., Plastretur AS		
Case 06: Principles of good practice involving loop closing		
Case project description The objective of the project is to establish a specific set of principles for good practice involving loop closing. The principles will be applicable in the industrialised world, but they should also serve as guidelines for the developing countries. For instance, the possibilities of loop closing should be an element in the planning of infrastructure. The participating companies represent different players in the value chain. Polimoon AS is a supplier of components (e.g. back and seat for HÅG chairs), systems (e.g. DynoTray for Tomra) and end-consumer products (e.g. canisters), HÅG is a supplier of chairs, Tomra Systems ASA is a distributor and collector. Plastretur AS is responsible for the collection of plastics in Norway. In the first phase of the project, the number of participating companies has been limited to those mentioned above. Later Elektronikkindustriens produksjonstekniske forening (EPF), Elektronikk-retur and others may join the project. The loop closing will be regarded in a life-cycle perspective. In order to optimise the possible environmental benefits of a closed loop, the eco-efficiency along the value chain must be assessed. Moreover, to ensure sustainable development, the overall eco-effectiveness must be evaluated. The project will assess cases of successful as well as less successful loop closing in order to arrive at a set of criteria for the establishment of well-functioning loops. The study will include aspects of infrastructure and collection, as well as sorting of the collected goods for reuse, material recycling and/or energy recovery. Logistics and economies are other important issues. Furthermore, innovative examples of "end-of-life systems" and product design solutions based on recycled components or materials should be collected and used as "inspirational material".		
Deliverables 1999/2000 ➢ Clarifying definitions ➢ Report from assessment of closed-loop cases (3-4 success cases and 1-2 failures) ➢ Criteria for successful loop closing ➢ Contributions to methodology for establishing closed loops		
Relevance to Core Project The case project will be an essential part of the further development of Core project #2, and will be the basis for development of future case orientation in 2000-2002.		
Person in charge in companies: Monica Hagen, Polimoon AS	**Person in charge P2005:** Professor Sigurd Støren, NTNU	
Time schedule: Starts: 01March 1999 Ends: 31December 2000	**Budget:** NOK 300 000 in 1999	
	P2005: NOK 150 000 in 1999	**Companies:** NOK 150 000 in 1999

Table 7: Summary of Industrial Case # 06

<table>
<tr><th colspan="3">Hydro Aluminium AS, Hydro Petrokjemi AS, Norske Skog a.s.a., Statoil etc.</th></tr>
<tr><td colspan="3">Case 07: Development of information network system of Norwegian LCA databases</td></tr>
<tr><td colspan="3">Case project description
This case project is an important element in improving Norwegian LCA data and making it more readily available for communication between companies and other users of data. The case project is based on a pilot study carried out in 1998, where a format for representing LCA data, and a data network structure, have been developed. Further development and implementation of the LCA information network structure and LCA functionality will be carried out by the LCA laboratory at NTNU, in co-operation with Østfold Research Foundation (STØ). The time horizon of the project is 1999-2001.

During the case project, the network structure and quality assurance system of the LCA data will be implemented. The project work will also include implementation and quality assurance of the LCA databases locally in the participating companies. Other companies, industry institutes etc. will also be invited to participate in the project.

The project will be co-ordinated with similar projects taking place in Sweden and Denmark, where funding will be requested from the Nordic Industrial Fund. The project will also be co-ordinated with ongoing ISO activities to develop a common data format for LCA studies.</td></tr>
<tr><td colspan="3">Deliverables 1999-2001
➢ Information network structure on the Internet
➢ A format for LCA data to facilitate communication between users
➢ Establishment of local LCA data bases in Norwegian companies
➢ A data base with generic LCA data from Norwegian sources</td></tr>
<tr><td colspan="3">Relevance to Core Projects
The LCA database network structure will be an important element in the development of LCA activities in the NTNU system, and in all P2005 research activities. The project will also be important for further development of LCA activities in Norway, by improving quality and facilitating the communication of LCA data.</td></tr>
<tr><td>Person in charge in companies:
Senior Vice Director Rolf Marstrander, Hydro Aluminium</td><td colspan="2">Person in charge P2005
Dr. techn. Ole Jørgen Hanssen</td></tr>
<tr><td>Time schedule:
Starts: 01 March 1999
Ends: 31 December 2001</td><td colspan="2">Budget:
NOK 225 000 in 1999</td></tr>
<tr><td></td><td>P2005:
NOK 75 000 in 1999</td><td>Companies:
NOK 150 000 in 1999</td></tr>
</table>

Table 8: Summary of Industrial Case # 07

<table>
<tr><th colspan="3">Various companies from the manufacturing industry</th></tr>
<tr><td colspan="3">Case 08: Eco-responsible companies in the manufacturing industry</td></tr>
<tr><td colspan="3">Case project description
This case project is connected to Horizontal activity #1: Eco-responsible corporate cultures in the Norwegian manufacturing industry. A general background for this activity is the transfer of eco-responsibility from government to industry and market. When companies and the market are to assume a responsibility formerly in the hands of the government, it brings organisational and strategic challenges to the companies. When focusing on these challenges, it is important to clarify what the transfer of responsibility implies.

There are different strategies in different countries and different cultures both on the governmental level and among companies. For example, Sweden has made many specific regulations for extended producer responsibility (ERP), while Norway has transferred the responsibility through the general health-environment-safety (HES) regulation, which is quite radical compared to many other countries. At the company level, environmental management systems such as EMAS and ISO 14000 have been used as a response to the demand for eco-responsibility.

In its initial phase, this case project will attempt to clarify how these national differences affect the companies' environmental strategies by especially focusing on how companies with sales and production in various countries develop and handle eco-responsibility. It will also be of interest to ascertain which understanding the governmental institutions in various countries have of the notion of eco-responsibility, and their opinion on future trends within this area. Finally, it will be important to see which organisational change processes the transfer of eco-responsibility has caused and will lead to at the company level.

By studying the development of environmental policy on the company and governmental level in an international context, this case project aspires to produce valuable knowledge for both core projects.</td></tr>
<tr><td colspan="3">Deliverables 1999/2000
➢ Establish contact between research institutions and core companies in P2005 industrial ecology, and draw up more detailed descriptions of issues for research
➢ Report on governmental strategies and the transfer of eco-responsibility
➢ Prepare material for later publications
➢ Develop further research strategies for Horizontal activity #1 and continuation/expansion of the case</td></tr>
<tr><td colspan="3">Relevance to Core Project
The case project will be an essential part of the further development of Horizontal activity #1, and will be the basis for development of future case orientation in 2000-2002. The activity is relevant to all companies, and is important for all the research strategies in Core projects #1 and #2.</td></tr>
<tr><td>Person in charge in companies:
N.N. (to be determined later)</td><td colspan="2">Person in charge P2005:
PhD Thomas Dahl, Sintef IFIM</td></tr>
<tr><td>Time schedule:
Starts: 01 March 1999
Ends: 31 December 2000</td><td colspan="2">Budget:
NOK 200 000 in 1999</td></tr>
<tr><td></td><td>P2005:
NOK 100 000 in 1999</td><td>Companies:
NOK 100 000 in 1999</td></tr>
</table>

Table 9: Summary of Industrial Case # 08

7. MULTIDISCIPLINARY CONTRIBUTIONS

The table below shows the research departments that will be most involved in each of the core projects and industrial cases. The use of time by the project partners is not shown. A bold **R** shows that the given department will be responsible for the given activity.

	Østfold Research Foundation (STØ)	Ålesund College	Sintef Production Techn. (Techn. Management)	Sintef IFIM (Techn. Management)	NTNU Dept. Product Design (IPD)	NTNU Dept. Materials Techn. (IMM)	NTNU Dept. Hydr. & Env. Eng. (IVB)	NTNU Dept. Thermal Energy & Hydro (TEV)	NTNU Dept. Physical Chemistry (IFK)	NTNU Dept. Ind. Econ. & Tech. Man. (IØT)	NTNU Dept. Sociology & Pol. Science (ISS)	NTNU Dept. Psychology (PSI)	NTNU Dept. Social Economy (ISØ)	NTNU Industrial Ecology Programme (IndEcol)
Core projects														
Core project #1: ▪ Research Strategy 1.1. ▪ Research Strategy 1.2.	 **o**		 **o**		 **o**					 **R**		 **o**		 **o**
Core project #2: ▪ Research Strategy 2.1. ▪ Research Strategy 2.2.	**o** **o**				 **o**		**R** **R**	**o**	**o**	**o** **o**	 **o**		**o**	**o** **o**
Industrial cases														
Case 01			**R**		**o**					**o**				
Case 02		**o**			**o**		**o**			**R**				
Case 03	**o**				**R**	**o**				**o**	**o**	**o**		
Case 04	**o**						**R**	**o**	**o**	**o**			**o**	
Case 05	**R**				**o**		**o**	**o**		**o**				
Case 06			**o**		**o**	**R**	**o**					**o**		
Case 07	**o**		**o**		**R**	**o**			**o**	**o**				
Case 08			**o**	**R**						**o**		**o**		
Common activities														
Horizontal activity #1: ▪ LCA laboratory ▪ Eco-responsible corp. cultures	**o**		 **o**	 **R**	**R**					**o** **o**		 **o**		**o** **o**
Horizontal activity #2: ▪ Terminology ▪ Communicating IE ▪ IE consequences for industry	 **o**			**o** **o**				**o** **o**		**o** **o** **o**	 **o** **o**	**o** **o**		**R** **R** **R**

Table 10: Involvement of research departments and institutions in P2005 IØK

The persons in charge of each research strategy, industrial case and horizontal activity will be given the delegated responsibility to draw upon persons and competence in the different research departments. Hence, the table above is more an indication of the interdisciplinary involvement of departments than a fixed a priori decision on how to carry out the individual research activities. In general, however, we wish to develop a dynamic network project organisation rather than a fragmented and hierarchical organisation where all research activities proceed as parallel and separate activities.

8. RELATIONSHIPS TO OTHER PROJECTS WITHIN P2005

With its focus on eco-efficient products, production and recycling systems P2005 Industrial Ecology has defined research areas with several important connections to the other priority areas within P2005. As reflected in the state-of-the-art report, the trend towards a more product-based environmental policy gives important directions for our research, while simultaneously creating common grounds with Integrated Product Development (IPD) and the Extended Enterprise. The research strategies in Core project #1,"Eco-effective supply chain management in industry" and "factor X development of technical systems" illustrate this point. In core project #2 and the research strategies "Evaluation of eco-effectiveness in recycling systems" and "Principles of good practice in local and national recycling systems" these parallels can also be seen quite easily. It should also be mentioned that the development of the LCA laboratory, which is specified as a horizontal activity in our research plan, will be carried out in close co-operation with IPD and the Department of Product Design, NTNU.

In addition to the thematic relationships described above, many of the companies involved in P2005 Industrial Ecology also have strong interests in other priority areas. This is related in particular to IPD, but the planned priority area Flexible, Reliable and Efficient Production has also been found to be of particular relevance for some of our industrial partners. Indeed, the possibility of sharing resources between the priority areas has been a condition of the participation of several core companies now involved in P2005 Industrial Ecology. Our general impression is that the potential for mutually enriching co-operation across priority areas is very good, and it is a challenge for all of us to further develop and strengthen the structures that will also make this happen in practice.

Some comments should also be made on the establishment of a "centre for learning corporations" as part of the P2005 activity. From our perspective, it is very important to underline the need for long-term thinking in this project, in addition to the focus on dynamics and continuous learning skills. The ability to predict future needs for new knowledge is also a crucial factor in a very rapidly changing industrial reality, and in this respect the use of scenario techniques will be a useful tool. It is also suggested that the focus should be slightly expanded, from learning processes in industry to more comprehensive decision-making processes/patterns, where both industry and other relevant actors in society are taken into consideration. We recommend co-operating with the RAND institution in the USA, which has special competence in this area.

9. BUDGETS

The tables below show the accepted budgets for the period 2000-2005 for P2005 Industrial Ecology. The budgets are based on the fact that there will be a given funding (in cash and in contribution in kind) by NTNU itself, as well as cash funding from the Norwegian Research Council, NFR. The overall budgets of the Industrial Ecology activity at NTNU during the period 2000-2005 amounts to about NOK 43,5 million, out of which the Norwegian Research Council contributes with NOK 25,1 million. On top of this come considerable contributions in kind from the industrial companies involved, adding up to an amount of more than NOK 10 million during the whole project period.

Table 11 shows the budgets for NTNU's own contributions, and Table 12 gives the contibutions from the Norwegian Research Council.

Table 11: A budget for NTNU's own contributions to Industrial Ecology during the project period 2000-2005 (in 1000 NOK).

Funded by NTNU (i.e. NTNU funds to the Industrial Ecology Programme at NTNU):

Note	Activity	2000	2001	2002	2003	2004	2005	Total
1	Basic funds to IndEcol	920	920	920	920	920	920	5520
2	Development of study programme	1100	350					1450
3	IndEcol Forum network funds	245	245	200				690
4	Postdoc scholarship	300						300
5	PhD scholarship	300	240					540
6	Working time 25% 6 persons	1070	1070	1070	1070	1070	1070	6420
7	Working time 10% 8 persons	570	570	570	570	570	570	3420
	TOTAL	**4505**	**3395**	**2760**	**2560**	**2560**	**2560**	**18340**

Notes:

1 Annual central funds at NTNU
2 Strategic funds to develop new courses in the IndEcol programme
3 Annual funds for interdisciplinary networking at the university
4 Scholarship to Martina M Keitsch
5 Scholarships to Lars B Johansen / Hilde Opoku
6 Working time (contrubution in kind) for IndEcol key faculty: prof. Helge Brattebø, prof. Annik M Fet, prof. II Rolf Marstrander, prof. Sigurd Støren, prof. Anders Skonhoft, 1.aman. Marit Reitan.
7 Working time (contribution in kind) for IndEcol faculty: 1. aman. John Hermansen, 1.aman. Mette Mo Jakobsen, prof. Knut Erik Solem, prof. Britt-Marie Drottz Sjöberg, prof. Terje Malvik, prof. Audun Øfsti, prof. Bjørn Munro Jensen, prof. Johan Hustad.

Table 12: A budget for the accepted contributions from the Norwegian Research Council to P2005 IØK (in 1000 NOK).

Funded by The Norwegian Research Council (direct NFR funds to the P2005 IØK project):

Note	Activity	2000	2001	2002	2003	2004	2005	Total
1	Budgets R&D research plan	3000	3000	3000	3000	3000	3000	18000
2	2 PhD scholarships	760	760	760	760	760	760	4560
3	Prof. II scholarship	200	200	200	200	120		920
4	Postdoc scholarship	440	240			480	480	1640
	TOTAL	**4400**	**4200**	**3960**	**3960**	**4360**	**4240**	**25120**

Notes:

1 NFR contract funds to the R&D research plan in Industrial Ecology
2 Two PhD scholarships (Håvard Solem and Kristin Støren Wiggum)
3 Adjunct professorship in LCA (Prof. Ole Jørgen Hanssen)
4 Postdoc project in LCA (Dr. Edgar Hertwich)

10. P2005 INDUSTRIAL ECOLOGY - SUCCESS CRITERIA AND AIMS

10.1 Introduction

This memo briefly outlines the overarching challenges and strategic interests of Industrial Ecology in the research program P2005, and establishes success criteria and quantifiable aims for the evaluation and control of special areas within this field.

10.2 Overarching challenges

The overarching challenge for P2005 Industrial ecology is to ensure that expertise is developed in relation to:

i) The challenges that the manufacturing industry will have to tackle with a view to combining a high degree of environmental and resource efficiency with competitiveness in a market – and society – where ecological considerations and eco-efficiency are becoming more and more important.

ii) Balancing considerations of what are good strategies for eco-efficiency on the corporate level and the macro level in society both in the short and long run.

iii) The formulations of an environmental policy framework and measures from the public authorities with respect to manufacturers and consumers.

iv) The challenges and possible environmental gains to be found in various types of network collaboration, along and across the value chain.

v) Instantiation of new principles and methods for assessment and implementation of lifecycle-based improvement measures, with the aim of attaining eco-efficient products and production systems in industry, creating eco-efficient systems for recycling and extended producer responsibility.

10.3 Strategic interests for Norwegian manufacturing industry and for NTNU

The success criteria will need to focus on the central requirements and strategic interests of the Norwegian manufacturing industry and NTNU. These strategic interests feature the:

Strategic interests for Norwegian manufacturing industry:

- The industry has incorporated and can document environmental and resource-efficient solutions in their systems for management and quality assurance, and in their production and product development.
- Short-term measures support long-term strategies where the industry's environmental responsibilities and external dialogue help move social development in the desired direction.
- Environmental considerations and investments are vital premises for the company's competitiveness in the market.
- Methods and solutions are adapted to what the companies are able to do.

Strategic interests for NTNU:

- NTNU's focus in the field is coordinated by IndEcol – the key is thus to ensure that P2005 is an important measure for strengthening NTNU via IndEcol as a program, by giving priority to:
  - recruiting (students and research scholars), and developing the expertise of employees
  - research-based teaching (new IndEcol multi-faculty study program launched in the fall of 1999)
  - interdepartmental cooperation, particularly linking knowledge in technology and social science
  - industrial collaboration (core companies) and societal contact
  - internationalization and cooperation with other leading universities
- In spite of its broad interdisciplinary approach, P2005 IØK is well focused, and is developed according to a controlled academic progression, with good central coordination with the other IndEcol activities (LCA lab, strategic university program, teacher and research scholar forum, teaching, other IndEcol companies).

10.4 Success criteria for P2005 Industrial ecology

There are two types of success criteria, external criteria focusing on the development of expertise in the Norwegian manufacturing industry, and in-house criteria focusing on the development of expertise at NTNU.

Success criteria focusing on the Norwegian manufacturing industry:

1) P2005 IØK develops expertise in collaborating companies in connection with future-oriented strategies and eco-efficient solutions, with respect to products, production, manufacturer liability and recycling.
2) Collaborating companies are aided in adopting suitable methods that will help each company develop and incorporate more eco-efficient and competitive solutions in their corporate case programs in P2005 IØK.
3) Other companies in the Norwegian manufacturing industry learn about findings and recommendations from the project and with the methods and solutions used by the project via reports, publications and seminars under the auspices of P2005 IØK.
4) P2005 IØK contributes to a dialogue and transfer of knowledge to the environmental authorities, NGOs and the general public with respect to good environmental strategies and integrated solutions.

Success criteria focusing on NTNU:

1) Long-term and interdisciplinary focus on recruiting research scholars and students as part of the core projects and corporate case program of P2005 IØK.
2) P2005 IØK aids the process by developing new education programs in the IndEcol study program, emphasizing development of both theory and methods and using corporate case studies in the teaching. Moreover, P2005 IØK teaches courses in relevant study areas at NTNU.
3) The institutions involved in P2005 IØK strengthen their industrial cooperation in this field, emphasizing projects with broader academic issues (system engineering approaches) with respect to external environments and lifecycle topics. Individuals in IndEcol's educator forum join P2005 IØK, aiming for greater contact with industry and the development of their own expertise.
4) P2005 IØK supports the prioritization of national and international collaboration, including with:

- Norwegian academic communities such as Sintef, STØ, BI, and selected regional colleges
- MIT, GeorgiaTech, Yale, TU Delft, KTH with respect to software development in the industrial ecology field

- TU Chalmers and DTU Lyngby with respect to method development – LCA
- The Leuven network – distance teaching and further education modules from the course package 'ELCE2000'

5) P2005 IØK contributes to publishing papers, sharing knowledge and holding conferences (including continued collaboration with NTVA – the Norwegian Academy of Technological Sciences)
6) P2005 IØK is included as a part of NTNU's coordinated work in the field, under the auspices of IndEcol, with the project manager and coordinator based at IndEcol's program secretariat.

10.5 Quantifiable aims for P2005 Industrial ecology

P2005 is an extensive research and expertise development program of many years' standing with high interdisciplinary and internationalization requirements. This also applies to P2005 Industrial Ecology. Quantifiable aims are required, but it is acknowledged that these will not be overly detailed or rigid. A common pattern shall be used for quantifiable aims for all the areas of P2005. In keeping with the stated aims of the Program Board, the basis here will be: i) utility value for industry, ii) contribution to restructuring of NTNU and iii) scientific results.

The aims for P2005 IØK are shown in the table below. Unless otherwise stated, the figures apply to the whole project period for P2005 up to 2005. The figures are minimums for the activity.

For industrial applications a distinction has been made between the participating core companies and other companies (VARP companies and others outside VARP). The core companies are those that have signed collaboration agreements with P2005.

When it comes to assisting in the restructuring at NTNU, emphasis must be given to the vision in NTNU's strategy plan – Creative, Constructive, Critical - "*Through leading academic communities NTNU shall ensure and renew national technological expertise. With strong disciplines and academic variety NTNU shall enhance understanding of the interplay between culture, society, nature and technology."* Here P2005 will be particularly focused on interdisciplinary cooperation in research and teaching, targeted cooperation with other academic communities in Norway, and internationalization in the form of professional collaboration with other leading universities abroad.

As to scientific results, importance is attached to publications, doctoral theses, majors and diploma papers, and seminars and conferences, based on common, incorporated quality requirements.

Quantifiable aims of P2005 IØK	Number
Industrial utility value	
- involved core companies	3
- other companies involved	10
- carry out industry case studies in the project	10
- company feedback on results and utility effect	3 + 10([1])
- seminars with broad participation from all involved companies, and authorities and NGOs	1 per year
- survey of Norwegian manufacturers, environmental authorities and NGOs to ascertain whether P2005 IØK's issues and results are known and perceived as useful	1
Contribution to restructuring at NTNU	
- new courses with curriculums based on P2005	6
- courses with curriculums to be improved on the basis of P2005	4
- new courses with curriculums on doctoral degree levels with contributions from P2005	2
- involved arenas and networks at NTNU	1 ([2])
- other involved measures in keeping with NTNU's strategy plan	1 ([3])
- internationalization/collaboration with leading universities abroad	3
Scientific and academic results	
- scientific publications in international periodicals with referees	2 per year
- scientific presentations at international conferences	3 per year
- Norwegian/Nordic scientific publications and reports	15
- popular science articles and leading articles in newspapers etc.	2 per year
- completed doctoral degrees financed by P2005	3
- majors studies in open study programs at NTNU	10
- diploma studies supported by P2005	10
- conferences	1 ([4])

Notes:

1) All involved core companies and case companies shall report on results and the utility value of their participation in P2005 IØK. The aim is for the actual utility value to be perceived positively and in a reasonable relationship to the resources put into the project, as perceived by the companies.
2) This applies to IndEcol Forum which is an interdisciplinary teacher network at NTNU as part of NTNU's Program for industrial Ecology (IndEcol).
3) P2005 IØK is strongly involved with IndEcol which is a strategic interdisciplinary program at NTNU.
4) P2005 IØK shall be responsible for a separate session on industrial ecology at an international conference under the auspices of P2005 towards the end of the program period.

10.6 Setting deadlines for aims and milestones in P2005 Industrial Ecology

The table below outlines deadlines and milestones for the quantitative aims set for the project and which have been indicated in Item 5 above. As agreed, the schedule covers the period up to and including 2005.

Year	**1999**			**2000**			**2001**			**2002**			**2003**			**2004**			**2005**		
Tertiary	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Industrial utility:																					
- involved core companies	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
- other companies involved			10	10	10	10	6	6	6	4	4	4									
- completed industry case studies						6			4			4									
- company feedback on utility value			13			13			9			7			3			3			3
- seminars with broad participation				1			1			1			1			1			1		
- surveys										1									1		
Contribution to restructuring at NTNU:																					
- new course based on P2005						3			3												
- improved courses						2			2												
- doctorate courses based on P2005												1						1			
- involved arenas/networks	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
- collaboration with other leading universities abroad			3			3			3			3			3			3			3
Scientific and academic results:																					
- publications in international periodicals with referees			2			2			2			2			2			2			2
- international conference presentations			3			3			3			3			3			3			3
- Norwegian publications/-reports						5			2			2			2			2			2
- popular science articles and leading articles in newspapers			2			2			2			2			2			2			2
- completed doctorate degrees financed by P2005															2			1			
- majors theses in open studies relating to P2005						2			2			2			2			2			
- majors theses Civ. Eng. relating to P2005						2			2			2			2			2			
- International conference																				1	

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