Industrial Ecology Programme

Annual Report 2007

NTNU
Norwegian University of Science and Technology

Directors column

Edgar Hertwich

We recognize turning points in history only after they have occurred. Today we can look back at 2006 and see that it was the turning point in the climate debate, internationally with the Stern Review and An Inconvenient Truth, and in Norway with a scary event – green Christmas! This year, the 4th Assessment Report of the International Panel on Climate Change – and the Nobel Peace Prize for the IPCC and Al Gore – only confirmed this change. Unfortunately, the recognition that climate change is a serious threat requiring a rapid response hits the world unprepared: the public funding of renewable energy research is at an all-time low and the world has grown comfortable with emissions-intensive habits and a development pathway that requires the use of massive quantities of fossil fuels. So far, politicians have not acted on their promises and individuals have responded as if they were powerless, or not concerned.

The sudden prominence of climate change has clearly had a big impact on us at IndEcol. All of a sudden our research is in public demand. Christian Solli has made a climate calculator for the national public TV station and appeared on TV, Glen Peters has been interviewed by the Wall Street Journal, and Stig Larssæther's idea to develop climate-neutral living arrangements in an experimental residential development has been taken up in the coalition agreement for the new municipal government in Trondheim. Several of us have been interviewed about the environmental aspects of biofuels. We also see that there is an increased interest in our courses.

In 2007, we also had the pleasure to welcome two new faculty members, design-for-sustainability expert Casper Boks who comes from TU Delft and "iron man" Daniel Müller from Yale University. We have great expectations to them! On the other hand, IndEcol co-founder Sigurd Støren has become an emeritus. Sigurd's efforts and enthusiasm have contributed a lot to the development of our program, and I would like to thank him for his efforts.

Of course we look forward to 2008! We are all involved in exciting research projects that have a real contribution to make to important problems: understanding the dynamics of infrastructure development, determining the role and effectiveness of national policies for the development of the renewables industry, modeling structural changes in the Chinese economy and emissions, assessing the environmental tradeoffs of climate mitigation, and finding ways to increase the eco-efficiency of the Mongstad refinery.

The Industrial Ecology Programme (IndEcol)

IndEcol is a matrix organization coordinating teaching and research in industrial ecology at the Norwegian University of Science and Technology, NTNU. The programme was initiated in 1994 on suggestion of Norwegian industry. A comprehensive educational curriculum was launched in 1999 and turned into an international MSc programme in 2005. Faculty and PhD students affiliated with IndEcol also belong to disciplinary departments where they are employed.

In 2007, 6 MSc and 2 PhD degrees were awarded. 11 Master of Technology students took their thesis at IndEcol. 1 book, 12 journal papers, 5 book chapters, 4 IndEcol reports and 2 working papers were published. At the end of 2007, 17 PhD students and 7 Post Docs are affiliated with IndEcol.

Advisory board: Ingvald Strømmen (leader), Olav Fagerlid, Bjørn Hafskjold, Frederic Hauge, Harald Rensvik, Kjell Øren.

Faculty committee: Casper Boks, Helge Brattebø (director, MSc programme), Gunnar Fermann, Annik Magerholm Fet, Edgar Hertwich (director), Anders H. Strømman, Sigurd Støren.

Student representatives in 2007: Michal Gryczon, Magnus Løseth

PhD/PostDoc representative: Håvard Bergsdal

Johan Pettersen defends dissertation

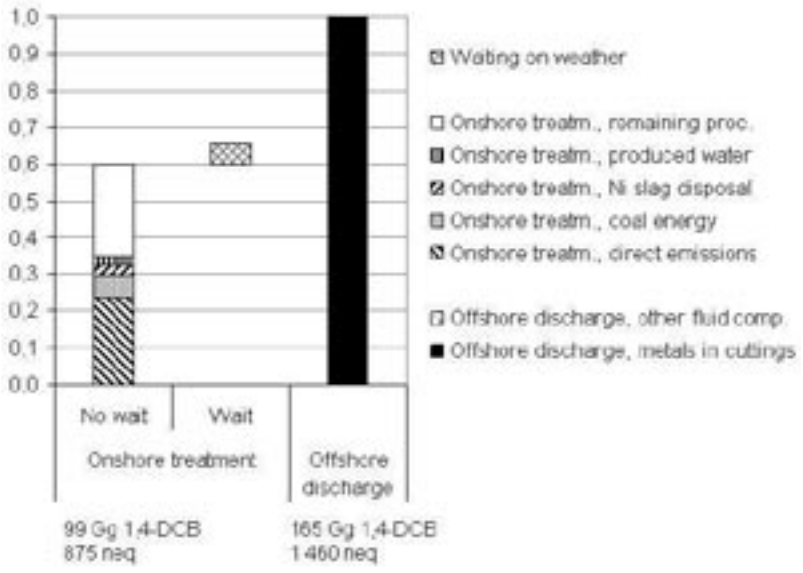
IndEcol would like to congratulate Johan Pettersen as he completes his PhD later this month. He will defend his thesis, “Overall evaluation of offshore drilling fluid technology: Development and application of life-cycle inventory and impact assessment methods” on December 17, 2007 in Trondheim. We asked him to share a little about his experience in IndEcol.

Why did you decide to pursue a PhD in Industrial Ecology? I completed a MSc Degree in Biotechnology at NTNU while taking many courses in the Industrial Ecology Programme. I found Industrial Ecology to be an interesting field as it does not provide any ready-made answers. At the same time, it offers tools and a perspective that can be applied to all kinds of situations. While completing my master’s thesis, I was part of a summer student project looking at the environmental impacts of weight materials in drilling fluid. During that project, I came in contact with people at Statoil that were interested in using LCA to assess drilling fluid technology. After completing my master’s thesis on modeling the ecotoxic effects of marine pulse-emissions, I got the opportunity to continue exploring LCA through a PhD project financed by Statoil.

What is your PhD thesis about? The goal of my thesis is to compare alternative offshore drilling technologies. Life-cycle assessment is used to quantify the environmental impacts of alternative drilling technologies, and it offers the broad perspective necessary to evaluate overall performance. In order to make overall evaluations I have looked at several issues related to offshore activities, including the difference between the toxic effects of pulse and continuous marine emissions, the human health damage from crane-lift accidents, and the long-term leaching of heavy metals from drilling waste deposits.
In my study I compare alternatives for density control in drilling fluids (ilmenite versus barite), offshore loading systems (crane-lifts versus a hydraulic system), base drilling fluids (water-base versus oil-base), and waste treatment of cuttings drilled with water-based drilling fluid (offshore discharge versus onshore treatment). A well located in the Barents Sea is used as reference.

Transport and energy processes are important to the final conclusions of the study. They are found to represent the trade-off impacts in the comparison of barite and ilmenite, loading technology, drilling fluid composition and drilling waste treatment. Ilmenite produced in Norway has a shorter transport distance to the user, and the hydraulic system uses more energy meaning that emissions not related to accidents are increased compared to crane-lifts. The preferred options are ilmenite, due to better leaching performance; the hydraulic system, due to lower expected human health impacts; and oil-based drilling fluid, given local treatment which reduces transport emissions.

We wish Johan the best as he finishes his PhD and moves on to the next stage of his career. Although he’s not yet ready to reveal his future plans, we do know he has bought a house in the area. We hope that means we’ll be seeing him around Trondheim for awhile.



Marine aquatic ecotoxicity in 1,4-dichlorobenzene equivalents for onshore treatment of drilling waste compared to offshore discharge to sea bottom. The investigation shows that the “zero-discharge” solution only offers a 35-40% reduction in marine toxicity, at the cost of other incurred emissions to air and water onshore. Moreover, toxicity is dominated by metals leaching from the waste rather than organic substances, and several processes contribute toxicity for the onshore treatment of wastes.

Life as an IndEcol student

The first class of students from the MSc programme in Industrial Ecology graduated this Spring. In addition to the six students who had completed the full Master's programme, there was ten engineering students who had chosen to specialize with courses, project and thesis in Industrial Ecology, as part of their engineering programme. This event was marked by an award ceremony where the students presented the main findings from their Master's thesis work for the IndEcol community, and afterwards a reception.

From six full-time Master's students in the first class, the second and third consist of nine and ten students. IndEcol currently has students of different nationalities from three different continents: Norway, France, Italy, Romania, Singapore, and the U.S.

We have interviewed three of our current master's students to hear more about what it is like to be a student at IndEcol.

Catherine Izard

While finishing her bachelor's degree in Geology at Yale University in Connecticut, Catherine Izard decided she wanted to continue her studies at the graduate level and began to investigate her options. Upon the advice of her professor at Yale, she took a look at NTNU's Programme in Industrial Ecology. She was pleased to find a program focused specifically on her area of interest and located in a country she had always wanted to live in. She began the master's degree program in August 2006.

As one might expect, Catherine found the transition to living in Norway challenging at times, but now that she's been here over one year she says she is very glad that she came. She enjoys experiencing Norwegian culture firsthand and being exposed to different points of view. The Industrial Ecology Programme's focus on addressing policy-relevant problems of concern to society today appeals to Catherine and has contributed to her desire to pursue a doctoral degree in environmental policy. The tools and methods she has learned in the Industrial Ecology Programme will serve her well as she moves forward with her studies.

In her master's thesis project, Catherine is trying to characterize the anthropogenic tin cycle with the goal of quantifying stocks in society, identifying potential short- and long-term problems, and suggesting policy measures that could be taken to minimize environmental and societal disturbances. Of particular interest to Catherine is how tin use can be optimized from a sustainability perspective. In December, she will be presenting preliminary results of her work to the International Tin Research Institute in London. Catherine is advised by Daniel Müller.

Magnus Løseth

Magnus Løseth began his studies as a bachelor's level student in NTNU's Mechanical Engineering program. In time, however, his interest in environmental issues led him to take several courses in the Industrial Ecology Programme. He found that he enjoys IndEcol's multi-disciplinary, systems analysis approach to problem solving. It fits well with his way of thinking. As a result, Magnus is now a second-year master's student in Industrial Ecology.

Working with his advisor, Helge Brattebø, Magnus has been using material flow analysis to examine past and future greenhouse gas emissions from the Chinese power industry. Point Carbon, a leading company in the field of carbon market analysis located in Oslo, has provided the problem description and a co-advisor for Magnus' project. Throughout the course of his research, Magnus has had the opportunity to collaborate with Point Carbon researchers and has been given access to the data they had previously collected. Through cooperative agreements such as these, Industrial Ecology at NTNU provides students access to real-world experience working together with leaders in the environmental field and valuable networking opportunities.

The article continues on the next page.

MSc programme

In addition to his research, Magnus contributes to the success of IndEcol by acting as a student representative to the Industrial Ecology Programme Working Group. At their meetings, he provides feedback from a student's perspective and helps to shape the future of the program. He says that he likes being a student representative because he can convey the views of the students to the professors, and he has seen positive changes coming from the meetings.

Overall, Magnus says that he enjoys the working environment in IndEcol. He has found both students and professors to be very helpful and he has gotten to know many of them over the last several years. He also thinks that the smaller class sizes and the diversity of the student body lead to interesting class discussions in Industrial Ecology courses. Magnus is due to graduate in June 2008.

Caroline Cheng

After working for 12 years in the banking industry in Singapore and Hong Kong, Caroline Cheng decided she was ready to go back to school to pursue her interests in business and the environment. She found that NTNU's Industrial Ecology Programme provided an interdisciplinary curriculum that would allow her to do just that. Previously, she had studied business administration, specializing in accounting and international business, at theUniversity of Wisconsin at Madison, in the U.S.

When asked which Industrial Ecology course she has enjoyed the most she said she can't decide on just one. She said that really liked the introductory course, "Industrial Ecology," taught by Professor Helge Brattebø, because it gave her a very good overview of the field. In addition, she also enjoyed "Environmental Management and Corporate Social Responsibility." She liked it so much, in fact, that she is doing her master's thesis on that topic.

Caroline studies corporate social responsibility with Professor Annik Magerholm Fet. Recently, she has been working closely with the Norwegian bank DnB NOR. As part of her work with the company, she was invited to interview some of their managers to learn their perspective on corporate social responsibility. She also gave a presentation to their Corporate Affairs department on the Global Reporting Initiative sustainability reporting framework.

Master's theses presented at the Award Ceremony 2007

- Elisabeth Adlam: LCA of transportation fuels
- Eli Grong Aursand: Leisure boats -environment-friendly hull design: Production methods
- Ragnhild Børke: Energy efficiency in non-residential buildings: Motivation, barriers and strategies
- Torhild Kvam Fikseaunet: A comparative study of the environmental consequences of four scenarios for production of fish fingers with an LCA perspective
- Ann Iren Glimsdal: Accounting of GHG emissions from projects injecting CO2 for enhanced oil recovery
- Johanne Hammervold: Integrating LCA in the local energy planning for heating of buildings
- Øystein Hjelm: Development and assessment of symbiosis in an industrial park
- Erik Skontorp Hognes: Life cycle analysis of fuel value chains and vehicles
- Nina Holck Steen: Dynamic analysis of life cycle energy flows and the corresponding environmental and economic impacts for the residential building stock in Norway
- Bjørn Magnus Iversen: Material flow analysis and recycling developments of white goods at WEEE Recycling AS
- Marius Johansen: Dynamic material flow analysis of Norway's housing stocks and critical factors that influence upon floor area and material flows
- Petter Chr. Jønvik: Life cycle assessment of car carriers
- Thorbjørn Dobie Kveim: Evaluation of system and practice of reporting from surveys of hazardous waste in buildings
- Kyrre Sundseth: Assessment of energy technologies in a combined life cycle and environmental economics perspective
- Sandra Wilson: Material recovery of plastic packaging: the Ghanaian challenge
- Kjersti P. R. Øyen: ORWARE: system analysis for efficiency evaluations of future organic household waste scenarios in Oslo

Industrial Ecology as part of Solid Waste and Built Environment Research

Material Flow Analysis (MFA) is one of the cornerstones in Industrial Ecology research at NTNU, coordinated by Professors Helge Brattebø and Daniel Müller at the Department of Hydraulic and Environmental Engineering. Since 2000, the research on MFA has mainly focused the use of MFA as a systems analysis tool to develop a better understanding of the material flows and the eco-efficiency performance of various solid waste management and recycling systems. Such systems are complex in terms of their number of material flows and actors. MFA has proven to be of high value in structuring and examining their development over time, as a result of changing market and political priorities. During the past year our group has refocused its MFA research more strongly on examining the built environment. Toward this end we are working to quantify the material and energy flows required to serve society's growing stocks of buildings and infrastructure in order to improve the sustainability of these systems.

In 2007, four MSc projects and six MSc theses were carried out in our group. Examples of this activity are: dynamic MFA for the examination of waste electrical and electronic equipment (WEEE) systems such as TVs and refrigerator equipment waste flows; system analysis for organic waste scenarios in Oslo; dynamic analysis of the development of Norway's residential building stock (including floor area, material flows, waste flows, energy flows, technologies, environmental and economic impact, and influencing factors); analysis of the global tin cycle; and modelling of GHG emissions from the Chinese energy/power sector.

In 2007, we started two new PhD projects in addition to two ongoing ones. This activity includes research on the use of dynamic analysis of the Norwegian building stock with respect to the material inflows, the waste outflows and the energy consumption flows, as well as the environmental and economic impacts associated with these flows. We also examine similar aspects of the life cycle management of selected infrastructure systems, such as water and wastewater pipeline networks, and bridges. The research centres on developing and combining analytical methods such as MFA, LCA (life cycle analysis) and LCC (life cycle costing), in order to improve the understanding of how built environment systems behave and perform over time. We also examine the critical factors influencing the systems' environmental and economic performance, and how the phenomena of growing stocks and ageing systems challenge operation, maintenance and management strategies, particularly those related to the future implementation of energy efficiency, and greenhouse gas emission policies.

As a spin-off of a (very close to successful) European research project application for the 7th EU Framework Programme, we arranged an international workshop on "Analysing Stocks and Flows of the Urban Built Environment", at Bårdshaug Herregård, October 11-13. Thirty participants from 8 countries covered 25 scientific presentations and held group discussions on the following topics: urban form and built environment stocks; stocks and flows dynamics and modelling; environmental and economic evaluation; integration in urban planning and built environment management. This workshop and the international network also will be a basis for developing our future industrial ecology oriented research in the field of Sustainable Infrastructure. This is one of our Faculty's most important long-term strategic research programmes.

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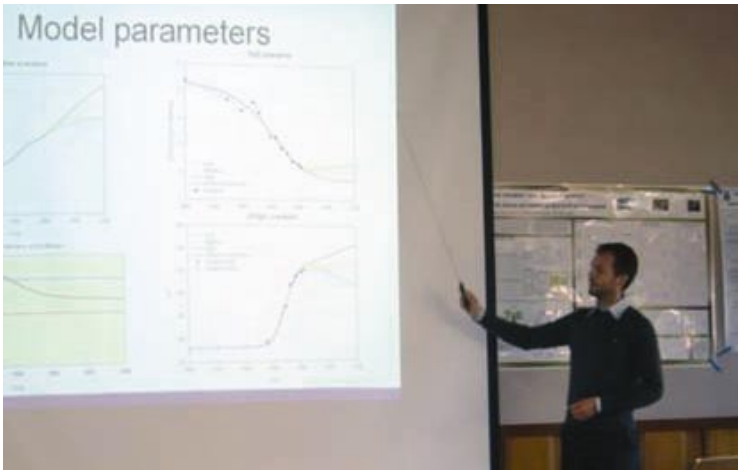

PhD student Håvard Bergsdal presenting his work at the Bårdshaug workshop

Climate-neutral living

In the spring of 2007, a group of researchers approached the government of Trondheim with a proposal for a climate neutral residential or mixed development within Trondheim's boundaries. The researchers included representatives from the Industrial Ecology Programme, NTNU's Faculty of Architecture and the Department of Interdisciplinary Studies of Culture, SINTEF-Architecture, and the National Housing Bank.

Subsequently, a series of meetings were held to help the municipality understand, and take ownership of, the project. After receiving a favorable reaction from Trondheim's mayor, Rita Ottervik, the proposal was incorporated into the formal policy document of the new city council in autumn 2007. By adopting this project, the local authorities want to move Trondheim into a leading position in the national race to reduce greenhouse gas emissions in Norway.

The vision of the project is to make Trondheim a pioneering region when it comes to developing and implementing climate neutral developments. This will be achieved through an innovative combination of technological solutions and integrated planning that will support low carbon lifestyle choices. All the phases of the building life span will be addressed, including the building process itself with focus on embodied energy of different materials and sourcing of local and reclaimed materials whenever possible.

In the use phase of the building, the aim is to combine existing passive/plus house concepts with exploration of new building concepts and materials. In contrast to most of the existing developments focusing on reduced climate impacts, the current project will include a focus on integrated planning that will address climate impacts also from activities taking place outside the house, such as transport, leisure time activities and food supply. Examples of such low-carbon lifestyle structures on the transport area can be car sharing schemes with zero emission vehicles, pedestrian and bicycle priority inside the developments and good integration with public transport.

In order to stimulate a more localized lifestyle, it is also important to address the quality of public and semi-public areas, greenery and easy access to larger recreational areas. Giving space to local commercial and cultural activities may also reduce the need for transport and at the same time stimulate the sense of community that will add to the overall quality of the development. Encouraging local food supply through gardens, box schemes or community-supported agriculture can also have this double function of reducing carbon footprints and increasing quality of life of the residents.

Walter Unterreiner, from IG Passivhaus Österreich, was one of the guest speakers in the workshop.

In addition to the political support from the municipality, the project received 100,000 NOK in strategic funds from NTNU. These resources were used to organize a workshop 1 - 2 November that would help develop a knowledge base supplying this project with national and international inputs.

The results from the workshop at Lian will be used as a basis for a grant proposal to the governmentally sponsored "Future Cities" program, as a part of a more general initiative from the municipality focusing on sustainable transport and energy use. The municipality has also started to consider potential locations for a climate neutral community. Together with these initiatives, the research community will also seek financing for a research program that will follow the development through qualitative and quantitative measures. We are proud that IndEcol is involved in such a practical application of its research, and look forward to more collaboration with the local government in the future.

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Political conditions for technological change

This has been a pretty active year. Early in 2007, I published my first book, *Governance, Growth and Global Leadership*. The book talks about the importance of structural economic change for long-term growth and development and of the role of the state in promoting this. This means an onus on new technologies and industrial growth. It also means an institutional perspective. There are political and institutional constraints on pretty much any human and industrial activity. New technologies and industries may not thrive in a business environment set up to cope with the needs of the industries of yesteryear. This is a point that I have made in four articles (one published in 2006, one in 2007, one accepted for publication in 2008 and one recently submitted for publication).

One of these, accepted for publication in *Review of International Political Economy*, deals specifically with the issue of vested interests. Politically, it is difficult for the state to make decisions that go against the interests of the most important vested interest groups. It will lose you support, and it may easily lose you the next election. Powerful vested interests are so because they have been around for a long time, having had time to grow and build influence. However, new and upcoming industries are typically not, as they have not had the time to grow and organize yet. The political and institutional framework is typically not geared towards the requirements of these groups, even if they are the future of the economy. Hence, it is important that the state curb the power and influence of vested interests.

This is also a point that I have made in a handful of interviews, one of which was for Forskning.no, both about the economic future of Norway, and about that of the planet as such. My book focuses on technologies and industries from the Industrial Revolution up until today, but the framework applies equally well to contemporary and future technologies/industries. With current environmental problems in mind, I have been emphasizing the fact that among the most likely growth industries of the present/near future are industries that are able to provide clean energy, in particular industries producing renewable energy. As an energy nation, this ought to be vital to Norway, and to the planet in general. The need for both energy and clean solutions is painfully obvious. However, it is not equally clear that Norway will become successful in this field, for the same reason that the theoretical framework in my book points out. Namely, the institutional structure in Norway is heavily geared towards the production of fossil fuels and vested interest groups in the Norwegian oil and gas cluster are so powerful that they can get more or less the regulations that they need to thrive. This, among other things, is the topic of a report on Norwegian industrial and energy policies that I wrote for the Norwegian think-tank Liberalt Laboratorium (LibLab) (due for publication in early 2008).

It was also the topic of a seminar that I attended in Oslo in October, sponsored by the E.ON Ruhrgas program. The main theme was the political economy of energy in Europe, with a focus on actors, institution-building, security, and different energy strategies. My presentation, which rounded off the seminar, focused on the topic of the Norwegian “oil-industrial complex” and on the political and institutional constraints on the growth of the renewables industry in Norway. I also sought to place the renewables industry in a larger context, as only the latest in a series of industries that have had the potential to transform the day and age in which they existed, thus also trying to substantiate the claim that this will be among the most important growth industries of the future. This presentation will, before the end of the year, be reworked into a chapter in a book edited by Gunnar Fermann (working title: The Political Economy of Energy in Europe).

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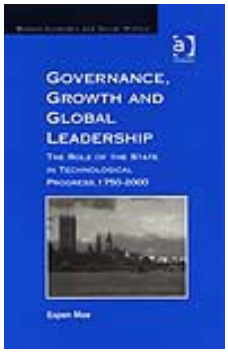
Climate policy

Our climate policy work concentrates on three areas: (1) The study of political conditions for technological innovation and change; (2) The modeling of global production-consumption networks to study how consumption and infrastructure investment gives rise to greenhouse gas (GHG) emissions; (3) The sustainability analysis of technologies and policies to investigate the co-benefits and tradeoffs connected to different mitigation strategies.

Some mitigation strategies help to reduce emissions of other pollution, while others lead to substantial increases in material use and other types of impacts. We apply an extended life-cycle assessment framework to identify and quantify these types of impacts.

The role of the state and vested interests



In his book “Governance, Growth and Global Leadership”, Espen Moe has showed how the state has played an important role in fostering the emergence of new industry, from textile production in the 18th century to present-day ICT-based industries. We are now employing the framework from the book to investigate the role of the state and vested interests in policymaking in the area of low-carbon technologies and industries. We investigate how institutional and political constraints prevent environmentally sound policies, how these constraints vary between countries, and how they can be overcome.

Trade, growth and GHG emissions

Glen Peters has developed a global model of production and trade to evaluate the CO2 emissions connected to different products produced in different places. According to our calculations, 22% of global fossil CO2 emissions are due to products traded internationally. There is a substantial danger that climate policy leads to structural changes which locate the production of emissions intensive goods in countries that have no obligation to limit emissions. We are a partner in the EXIOPOL project building a new and improved trade model. We are also investigating structural changes over time, scenarios for the future, and we are using this work in priority setting and in climate calculators.

UNEP Resource Panel

In November 2007, the United Nations Environment Programme launched the Panel for Sustainable Resource Management, which will summarize the state of the art of knowledge related to resource efficiency, material flows, prioritizing consumption activity, and decoupling resources and pollution from growth. As an invited panel member, Edgar Hertwich contributes to one of the initial policy papers on assessing resource effciency and environmental impacts.

Green procurement to reduce carbon footprint

The City of Trondheim has ambitious goals for reducing its greenhouse gas emissions but until now lacked a sufficient understanding of what these emissions were and how they came about. PhD student Hogne Nersund Larsen has investigated both the direct and indirect GHG emissions. His report focuses on emissions connected to the municipality’s own activities. 94% of the emissions are indirect emissions, i.e. connected to the municipality’s purchases of both services (such as bus transport and snow plowing) and operational inputs (electricity which accounts for 31% of the total, food and medicine for elderly care etc.). Schools and health care stand for the largest share of emissions. Purchasing more environmentally friendly goods and influencing suppliers are hence important strategies for reducing the city’s carbon footprint.

Mongstad Pilot

The Mongstad Pilot project focuses on possibilities for industrial symbiosis and improved eco-efficiency at the largest oil refinery in Western Norway. Our principal interest is to investigate new business activities that can closely integrate into the refinery, exchanging resources. The project is financed by StatoilHydro.

The start-up of the Mongstad project: Evjemo, Preizig, Riisnes from Statoil, and Hertwich were gathered at NTNU.

The aim of our research is to provide new approaches and tools to design and evaluate industrial symbiosis options involving a refinery, and to provide insights and advice to StatoilHydro and other relevant actors. We have decided to focus on two broad industries that are potentially relevant given geographical and economic considerations. These are other energy conversion facilities and aquaculture. We have also investigated the option for drying processes, but not pursued this beyond initial case studies.

2007 has been an important year for the Mongstad refinery because the government has finally approved the construction of a gas-fired combined heat and power (CHP) plant that will replace existing boilers. The government, however, requires that CO2 from the CHP is captured and stored from 2014 onward. The planned changes at the site provide an interesting context for our work, however, they also distract attention from our work as the refinery management is busy with planning and detailed decision making on the future configuration.

There are three groups at NTNU working on the project:

1. Professor Hertwich, Associate Professor Anders Strømman, PostDoc Xiangping Zhang and Researcher Christian Solli at the Industrial Ecology Programme/ Department of Energy and Process Engineering work on developing models of the entire symbiosis and evaluating different alternatives according to ecological and economic criteria.

This year we have worked on two issues: (1) Evaluating different heat and power options with carbon capture and storage (CCS) and, (2) the production of synfuels, both 2nd generation biofuels and synfuels from coal. We have modelled different systems that include the refinery and such new production systems, evaluated the efficiency, substance flow and exergy of the processes, and looked at heat integration issues. While Statoil has chosen to build a post-combustion CCS facility, our research results indicate some advantages of a pre-combustion solution. A pre-combustion solution entails first producing hydrogen. This hydrogen can also be used in the refinery directly, for synfuel production, or as a transport fuel. A pre-combustion solution hence offers flexibility, in addition to requiring less heat for recovering the amine-based solvent for the CO2.

Another issue that we have investigated is the production of 2nd [illegible]ngas route. The results confirm the low efficiency of the conversion process of biomass to a liquid fuel and the high area requirements.

2. Professor Heinz Preisig and PhD student Ivan Dones at the Chemical Engineering department work on modelling the Mongstad operations. They have recently focused their work on distillation, developing an approach to the initialisation of a distillation model that is easier and more reliable to use. The C-4 splitter (n-butane / i-butane) that is part of the gas plant (Vestprosess) was taken as an example. Some surprising new insights have been gained from this work, which give some indication on why the initialisation problem is so hard to solve, particularly if one uses simplified models, as is customary. A second subject is the issue of extracting the maximum information from a plant given a set of measurements available from the units and streams. A systematic method has been developed that analyzes the plant and the available measurements. The procedure adjusts automatically the granularity of the model to the level where one can perform the standard mass and energy balance-based analysis of plants. The software can generate a stand-alone daemon-like energy/mass analysis program, which can potentially run on-line if

it is hooked into the real-time data base system of the plant.

3. Dr. Jan Ove Evjemo at the Biology department is working on the development of aquaculture species/technologies suitable for warm water. More than half of the waste energy available from the refinery is cooling water at 25°C. The work related to lobster-farming was completed in August this year and has triggered substantial public interest. The popular science weekly *Teknisk Ukeblad* and weekly magazine of the daily *Aftenposten* produced features on this issue. The research has focused on the larval and the juvenile stages of lobster since this is the most complicated phase of the life-cycle.

This year the work has been related to feeding trails with small stages of lobster, and what impact specific fatty acids (DHA and EPA) in the diet have on growth and survival. Chemical analysis has been performed on both lobster and diets. The next aquaculture species to be tested is cod.

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Environmental management and CSR

Topics like industrial ecology, environmental management, corporate social responsibility (CSR), global supply chains and systems' understanding are becoming more connected as businesses are going global. The international conventions such as the Global Compact, the Millennium Development Goals, and the Global Reporting Initiative offer important guiding principles to businesses that want to meet the sustainability challenges.

Cleaner production (CP) techniques, environmental accounting (EAc), input–output (I/O) analyses, life cycle assessment (LCA), and environmental management (EM) are being used by companies to evaluate their overall environmental performance. These tools and techniques can be classified as process-, product-, or management-related. These techniques can also be applied at different system levels, for instance at a corporate site, for a product's life cycle, or at a global supply chain.

Two overall research challenges are identified for this research at NTNU:

I. To improve the knowledge and understanding of the challenges faced by companies along the global value chain. The focus is on the environmental and social responsibilities; however, understanding the dynamics, interactions and juridical aspect between the different actors in the global production systems is essential.
II. Based on this understanding, we contributed to the development of methodologies and guidelines which facilitate sustainable competitiveness in a global system, and associated indicators.

In 2007 the research has primarily followed two axes; how can companies expand their environmental management systems to also include social aspects, and how to merge environmental (and social) management with supply chain management to expand the focus on environmental and social issues throughout the supply chains.

Social issues have primarily been integrated in the projects "Data assisted tool for sustainability product information (DATSUPI)" and "C(S)R in Global Value Chains: a Conceptual and

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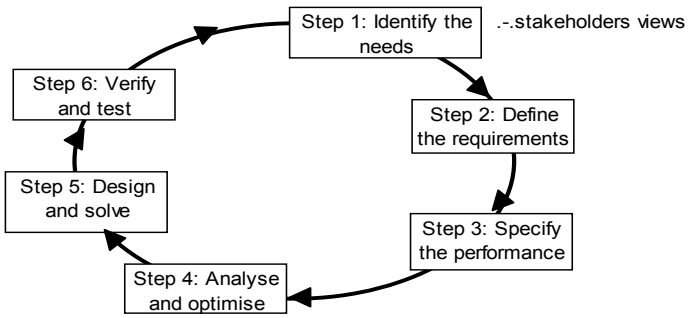

Systems engineering as CSR-management model

Operational Approach". The last one is addressing the social aspects from different perspectives, from a firm perspective, from a governmental perspective and from a global network/systems perspective. In DATSUPI the main goal is to develop a design tool based upon LCA-information and social-relevant information of furniture. The research also addresses emissions from furniture that could affect the health of the user without the necessity to run emission-tests of all products. The information could then be integrated into the Environmental Product Declarations as additional information. The project also seeks to include robust indicators addressing other aspects of the social performance of products. Both projects are national projects with Norwegian business partners, but the work is linked to international efforts on including chemical working conditions in Life Cycle Assessments.

Most environmental management systems are structured according to ISO 14001. The latest version shows a shift toward a stronger focus on larger systems and the companies are now instructed to identify the environmental effects caused by their activities, processes, and products. This means that a company cannot ignore the impacts caused by their products and the environmental burden given through the entire supply chain.

However, there is no recognized model for how to integrate CSR-awareness in supply chain management (SCM), neither is there a set of recognized and agreed upon CSR performance indicators to use in this process. The focus has thus been directed on the development of models and tools for CSR-driven supply chain management where knowledge on SCM and purchasing management is combined with environmental management tools and indicator development. A first model on how to combine these issues is developed and will presumably be published in 2008.

Similarly to EM there is a need to map the stakeholders' views, identify the significant aspects, do an impact assessment of the activities and products in a global system of actors, set up objectives and targets for improvements, and communicate this to the interested parties. This sets the requirements for multidisciplinary understanding and system thinking. To sum up, the change from site to global focus should be systematically done using different management tools by which companies will be able to build their sustainable strategies.

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Postgraduate School of Industrial Ecology: PSIE

The idea of this Marie Curie project was to organize European PhD courses in industrial ecology, bringing together the top experts on specific issues and eager PhD students and PostDocs. This year the first four PSIE-PhD courses have been taught in Bratislava, Prague, Ostrava and Guildford involving teachers from Leiden University, NTNU, Radboud University, TU Delft, and the University of Surrey.

We managed to collect 20-26 participants per course in one place for 2 weeks, creating a good climate for the exchange of ideas and networking among the young scientists. The course evaluations we have seen so far have been generally positive. Students appreciated the course content and high ambition level, the feedback on their own written work and presentations, and of course the social aspects of the course. This feedback supports the concept that coordinating PhD courses at an EU level makes a lot of sense so we hope to continue this type of collaboration with our partner universities.

MARIE CURIE ACTIONS

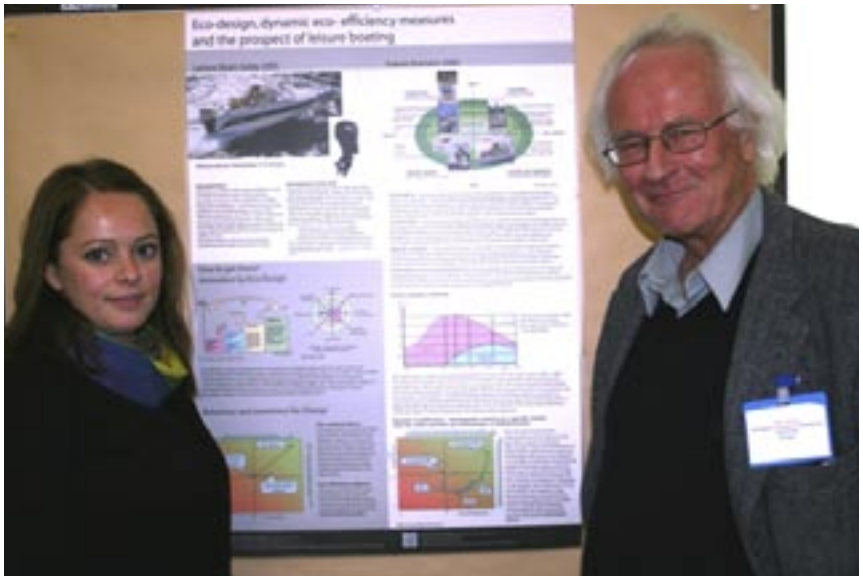
Sigurd Støren - a tireless retiree

Sgurd Støren, co-founder and well-loved professor in the Industrial Ecology Programme, retired earlier this year. You would never know that, however, by looking at the list of projects that he is still involved with. We are happy to report that although Sigurd officially retired two months ago, he continues to be active in his research and advising pursuits. In fact, he is still meeting with PhD and MSc students, and is working on projects related to eco-design and life cycle thinking and innovation two days a week.

Sigurd received his MSc in mechanical engineering from the Norwegian Institute of Technology (NTH) in Trondheim in 1964, and conducted post-graduate studies in materials technology and metal forming at NTH/SINTEF and abroad. From 1978 to 1986 he worked for Norsk Hydro, Karmøy on aluminum alloy-, process- and product development as head of the development center. While he was there, he participated in the beginning stages of aluminum recycling and was involved in looking at all phases of the life cycles of the material. It was then that his interest in ecology, which had been building for some time, was put into practice in his professional life. Sigurd names three forces that were pivotal in shaping his environmental thinking during the 1960s and 1970s: *Silent Spring* by Rachel Carson, the deep ecology movement initiated by Prof. Arne Næss, and the book *Limits to Growth*. He says that after reading Carson's book while he was in college, he realized that nature is not an indefinite resource and that pollution needs to be controlled.

In 1986, Sigurd began his career at NTNU as a professor in the Mechanical Engineering department. After he arrived, through talks with his contacts in industry, where Rolf Marstrander at Hydro Aluminium played a vital role, Sigurd and others at NTNU became aware of industry's acute need for graduates and scientists with a skill set that could be provided by an Industrial Ecology Programme. So, working closely with Massachusetts Institute of Technology-Professor John Ehrenfeld, Rolf Marstrander, and other enthusiasts at NTNU, Sigurd worked on creating a way for NTNU to give students a more total overview of environmental problems in society. Since that time, IndEcol has focused on developing systems and holistic thinking in students and meeting the needs of industry and governmental institutions.

While talking with Sigurd, it quickly becomes clear that he remains committed to the future success of the Industrial Ecology Programme. As he describes the history of the program, one gets the sense that he is proud of what has been accomplished so far and excited about the future potential. His dream is that the Industrial Ecology Programme will provide every professional working at NTNU/SINTEF and every student leaving NTNU with insight, methods, and tools that enable them to use their professional expertise to create a sustainable "Global Village" where aspects of technology, economy, ecology, ethics, culture and spirituality are included. We are deeply indebted to Sigurd for the important contributions he continues to make to IndEcol and wish to congratulate him on his "retirement."



Sigurd and master's student Eli Grong Aursand at the SCORE conference.

IndEcol welcomes two new faculty members

Casper Boks: New Professor in ecodesign

In January 2007, the Industrial Ecology Programme welcomed Casper Boks to its faculty. Casper comes to NTNU from the Design for Sustainability Program in the Industrial Design Engineering School at Delft University of Technology in the Netherlands. His research interests include sustainable product innovation and education with a focus on the organizational and managerial aspects of successful implementation of sustainable product innovation. Casper is particularly interested in the human factor in this implementation process. He points out that since people have the power to speed up or slow down environmental thinking in a company, it is important to study these potential barriers and enablers.

As a new professor in the Department of Product Design (IPD) at NTNU, Casper is helping to connect Industrial Ecology with Product Design by making the human and product elements more prominent. He thinks that the two fields can learn a lot from each other. As Casper notes, "Fortunately, products are increasingly seen and designed in a systems and life cycle perspective. Academic research has fuelled that trend. Understanding the role of the final user in sustainable design is one of IPD's main research interests".

At NTNU, Casper teaches Ecological Design, a course that is offered primarily to undergraduate students, although graduate-level students can also take it with additional course requirements. He thinks it's important to develop a student's individual engagement towards sustainability issues in his or hers future career – without being moralistic about that. He notes that several master's-level Industrial Ecology students have already taken his class. He also has done guest lectures for IndEcol courses and invited IndEcol professors to do the same for his course.

When asked why he was drawn to NTNU, Casper says that he found the product design department to be very attractive and the size of the program allows him to focus more on the quality of both his teaching and research. Luckily for us, his wife and three children were excited about making the move to Norway as well! He says that they are really happy to be here and are looking forward to learning to ski soon. Casper is one of those people who can ask you "Do you want to see my stamp collection?" and be totally serious about it. He is a fanatic stamp collector and has close to 100,000 different stamps in his dedicated walk-in closet.

Daniel Müller: New Professor in material flow analysis and the built environment

The Industrial Ecology Programme is pleased to announce the newest addition to its faculty, Professor Daniel Müller. Daniel is so new, in fact, that he just arrived in Trondheim a couple weeks ago. However, since he actually started working for IndEcol before he arrived, he has been able to jump into his responsibilities here without delay.

Before coming to NTNU, Daniel was an Associate Research Scientist at Yale University, in the U.S. He says that he was attracted to IndEcol, in part, because of its strength in applying industrial ecology methods, including life cycle assessment, input-output analysis, and material flow analysis, to policy-relevant problems of interest to a number of audiences. He was also attracted to NTNU by the opportunity it provides to work with the researchers and students

The article continues on the next page.

in IndEcol, some of whom he has known for years.

While at NTNU, Daniel hopes to build up his research program on what he calls two feet. On the first foot, he would like to examine the built environment, on the urban scale, and try to understand how cities grow. This means looking at material and energy stocks and flows related to the growth of cities, and the transition of existing cities into sustainable cities that use energy and materials much more efficiently. He hopes to combine data on material stocks and flows with GIS to provide results that will be useful and relevant to urban and regional planning commissions. For the second foot, Daniel is interested in the global cycles of materials, particularly metals. He has observed growing interest from mining companies and the metals industries to learn where their products are going, and where their (scrap) resources are coming from in the future. He hopes that these two feet will eventually link into one body. That is, he sees these two fields growing together because, as he explains, cities are the key drivers for global resource demand, and resource supply of cities increasingly depends on a global "hinterland" (e.g., metals, fossil fuels).

Daniel is also passionate about strengthening partnerships between IndEcol and representatives from industry and governmental organizations, to the benefit of everyone involved. For instance, he wants to continue IndEcol's tradition of exposing students to different perspectives to help them see how their work applies to real tasks and problems and give them a vision for what their future careers could look like. At the same time, he plans to organize workshops with environmental specialists from industry to share the tools used by IndEcol researchers.

In addition to his research, Daniel will be teaching a course entitled "Material Flow Analysis" in the spring 2008 semester. With all the knowledge and experience he brings to the department, we are certainly glad that he's here and we wish him and his family a hearty welcome to Norway.

CO2-calculators based on IndEcol research help inform environmental choices

IndEcol has been involved in several calculator development projects this year, most notably for Norway's largest women's magazine *Kvinner & Klær* (*KK*) and NRK, the Norwegian Broadcasting Network.

The 5/2007 issue of *KK* magazine featured a "How much do you pollute" calculator made by students Nina Holck-Steen and Ann Iren Glimsdal. Nina and Ann Iren also contributed to a double page of "Smart things to do to lessen your environmental burden" in the magazine. Nina has begun her PhD studies at IndEcol this Fall, while Ann Iren graduated last year and is now employed at Norsk Energi.

The calculator is partly based on work Nina has done during her IndEcol Apprentice period while a master's student, working with a model developed by Post Doc Glen Peters. An online version of the calculator has been used by the NRK, in connection with a TV series on the future of the Earth ("The Planet"). One of Norway's largest news papers, VG, also published a similar "climate calculator" - however, most people score very low on emission of CO2 in it, giving people too good a conscience about their habits, Nina says.

Her results indicate that the consumption of products and services by one member of a Norwegian household results in the emission of 5 tons of CO2 per year, plus other climate gases of 1 ton CO2-equivalents per year. The sustainable level, however, is estimated to be only 1.1 tons.

Screenshot of the CO2-calculator made for NRK: http://www.nrk.no/norge2020/

As a part of the project "Norge2020" at NRK, IndEcol researchers Glen Peters and Christian Solli produced a CO2-calculator for the web. IndEcol also provided expert guidance for the family which was reducing their emission in the series. This resulted in a small TV appearance at NRK1.

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