

# Annual Report 2008



## Industrial Ecology Programme



NTNU  
Norwegian University of  
Science and Technology



The end of the year and the start of a new year is a period for reflection and hope. This column is written on the day after Barack Obama has been chosen as the new president-elect in the United States; something that gives many of us reasons to believe that also from a sustainability perspective, the conditions for dealing with future global challenges have improved. Some are more skeptical; they consider Obama's promise that the USA will vigorously support global cooperation in fighting climate change as mere populist rhetoric to win votes. Also, with respect to the current financial crisis, conflicting opinions exist; some think it will cause governments and industry to focus on survival and not prioritize programs supporting sustainability. On the other hand, some hope or are even convinced that the current financial crisis provides a unique opportunity to transform our economies towards sustainability and international solidarity. Interesting in that respect is that recent research by PriceWaterhouseCoopers has shown that the financial crisis is not expected to affect the corporate social responsibility programs of the majority of companies, and that sustainable companies appear to be less affected by the current crisis.

For IndEcol, the ever increasing demand for input in the sustainability debate works in our favor, and we experience a strongly growing interest in what we are able to offer. We are lucky to be part of a university, and a faculty, where sustainability research is not regarded as a hobby but as

a strategic interest. Students, both inside and outside our program, are increasingly interested in following our courses. We are known for our high quality research (please take a minute to look at our publications list in this annual report), and we are able to collaborate with many partner institutions, and welcome visiting researchers frequently. In fact, IndEcol's programme director, Edgar Hertwich, is currently enjoying a sabbatical stay at the Department of Environmental Engineering in Zürich's ETH – which is the reason why I have been asked to partly take over Edgar's responsibilities in the program until he returns after August 2009. Check the People News section for more information about the changes in IndEcol (also for 2009, we already expect several new PhD students and postdocs to start in first few months), and where our graduates find interesting new jobs. One example is that IndEcol alumni Johan Pettersen and Christian Solli decided to start their own company MiSA AS – you will be able to read their about their first experiences in this report.

Other interesting reading in this report are contributions from the various professors connected to IndEcol, representing areas including sustainable infrastructure, environmental management, environmental politics, input-output analysis, LCA and material flow analysis.

We hope that you will enjoy reading this report!

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Cover photo by Arild Juul/NTNU SA

### Industrial Ecology programme

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 2008, 8 Msc degrees were awarded and 2 Master of Technology (MT) students completed their theses at IndEcol. 23 new MSc students and 3 MT students were admitted. During 2008, 23 PhD students and 6 Post Docs were affiliated with IndEcol, including 4 new PhD students who began their studies in 2008. 1 book chapter, 32 journal papers, and 4 IndEcol reports were published.

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

Faculty Committee: Rolf André Bohne, Casper Boks (acting director), Helge Brattebø (director, MSc programme), Gunnar Fermann, Annik Magerholm Fet, Edgar Hertwich (director), Elin Mathiassen (coordinator), Anders H. Strømman and Kjell Øren.

Student Representatives in 2008: Håkon Selvig Bratland, Lisa Marie Erlandsen and Rayson Ho.

PhD/PostDoc representatives: Håvard Bergsdal and Stefan Pauliuk

## PEOPLE NEWS



Photo: Elin Staurem, Artwork: Thomas Gibon

IndEcol welcomes Rolf André BOHNE to the faculty of NTNU. In August 2008, Rolf was promoted to an Associate Professor position with NTNU's Department of Civil and Transport Engineering, in the Building and Material Technology research group. He recently completed a Post-Doctoral Fellowship with the same group.

IndEcol welcomes Post Doc Karin VELTMAN, a chemist, who recently completed a PhD thesis at Radboud University, Nijmegen (NL) on modelling the bioaccumulation of chlorinated organic chemicals in marine foodchains. Karin is working on the ecological risks from CO<sub>2</sub> capture and storage, as well as on improving the assessment of marine ecological impacts in life-cycle assessment.

PhD-graduate Johan PETTERSEN and former researcher Christian SOLLI have started MiSA AS, a consulting company focusing on life-cycle assessment, carbon footprinting, and other tasks in environmental systems analysis. Prof. Edgar Hertwich and PhD student Hogne N. Larsen also hold a share in the company.

Recent IndEcol PostDoc Espen MOE has moved to the School of Policy Studies at the Kwansei Gakuin University in Sanda, Japan, on the outskirts of Kobe, where he will be starting on a two-year post doctoral fellowship

financed by the Japan Society for the Promotion of Sciences.

Recent IndEcol PostDoc Glen PETERS has become a Senior Scientist at the Center for International Climate and Environmental Research - Oslo (CICERO). Peters and his collaborators Christopher Weber, Gabo Duan, and Klaus Hubacek received the 2007 Best Environmental Policy Paper Award by Environmental Science & Technology, the No.1 ranked journal in its field, for a paper "Growing CO<sub>2</sub> Emissions - A Race between Increasing Consumption and Efficiency Gains". Congratulations!

Recent IndEcol PostDoc Asuka YAMAKAWA has started a new position as a PostDoc with the Pulp and Paper Group (PFI) at the Department of Chemical Engineering at NTNU. She is working on a project analyzing 3D data about wood fibers, a project which is a collaboration between SINTEF and PFI.

Recent IndEcol PostDoc Xiangping ZHANG has been appointed full professor in chemical process engineering at the Chinese Academy of Sciences. Congratulations!

IndEcol welcomes Anders ARVES-EN as a new PhD student. Anders has a Master in Engineering in Energy & Environment with specialization in Industrial Ecology.

Anders works with Prof. Hertwich on assessing the environmental impacts and benefits of offshore wind power and investigating opportunities for reducing these impacts. In 2008, Anders was the IndEcol person most cited by domestic news outlets. In a summer project, he showed that air travel was already responsible for 10% of Norwegian GHG emissions and that the recently accelerated growth would cause Norway serious problems in reducing its carbon footprint.

Welcome to Ryan BRIGHT, who is a new PhD student working primarily on environmental systems analyses of bioenergy systems. Ryan focuses on viable 2nd generation biofuel production technologies and the alternative uses of bioenergy resources for use in sustainable transport systems.

Stefan PAULIUK is one of two new PhD students who have joined IndEcol and the Material Flow Analysis research group. He obtained a Master in Theoretical Physics from the Friedrich Schiller University of Jena (Germany). Prior to joining NTNU on 1 October 2008, Stefan analyzed the structure of matter at the German Electron Synchrotron (DESY). In his Ph.D. thesis, which formally starts on 1 February 2009, Stefan will analyze the structure and dynamics of the global iron cycle.

IndEcol also welcomes new PhD candidate Gang LIU to the Material Flows Analysis group. He holds a Bachelor in Geographic Science from Beijing University (China) and a Master in Human Geography (Resource Economics and Energy Environment) from the Chinese Academy of Science. Prior to joining NTNU on 1 December 2009, Gang worked as a researcher in strategy development at the China National Petroleum Corporation. In his PhD thesis, Gang will analyze the multi-level aluminium cycle with explicit treatment of trade and analyze its energy use and emissions in various stages.



## INTERVIEWS WITH INDUSTRIAL ECOLOGY STUDENTS

### Hugo Johansen



The MSc programme in Industrial Ecology continues to attract students from a wide range of backgrounds.

While some enter the programme directly after finishing their undergraduate education, others choose to spend some time working first.

Hugo Johansen is an example of the second type of student. After finishing his bachelor's degree in information technology at HiNT, or North Trøndelag College, in Steinkjer, Norway, Hugo began to work for the Norwegian Air Force as a system administrator. He spent several years in that position before traveling to Australia for further study. While at James Cook University in Townsville, North Queensland, Hugo completed a Master of Information

Technology and a Master of Applied Science in Natural Resource Management and worked as a GIS-officer at the Kowanyama Aboriginal Shire Council for six months.

Hugo says that he first heard of the Industrial Ecology programme at NTNU when one of his Norwegian friends in Australia chose to return to Norway to attend the programme. "When I returned to Norway I was determined to do some more studying and I felt that the IndEcol programme was a good continuation of my studies in natural resource management, which also involved sustainability and similar subjects."

In his master's thesis Hugo hopes to create a GIS representation of the phosphorous cycle for the agricultural lands in a limited geographical area. When asked about his thesis, Hugo says, "In this work I have been lucky enough to get Prof. Daniel Muller as my supervisor. He does not only have an interest within the field of combining GIS with MFA but has also been able to put me in contact

with people who have knowledge and experience working with the phosphorous cycle. I have also been able to get in contact with Sør-Trøndelag County in order to obtain the data necessary to perform the study."

While he is finishing his master's degree in Industrial Ecology, Hugo is also working full-time as a Geographical Analyst for NAVTEQ, a company within the GIS sector. Although it can be difficult to work and study at the same time, Hugo says that, "So far, NAVTEQ has been very supportive of my studies and through flex-time has given me opportunities to attend lectures at varying times during the day, not to mention allowing me to study without further adding to a study loan."

"I feel that, so far, I have learned a lot about sustainability and hopefully by the end of this degree I will have an even greater understanding of material flow analysis and be able to use that in future employment."

### Master's theses presented at the Award Ceremony in June 2008

Name	Thesis Title	Advised by
Anders Arvesen	Direct and Indirect Energy Consumption of Households in Beijing	Edgar Hertwich
Ryan Bright	Hybrid Life Cycle Assessment of Wood-based Biofuel Production and Consumption Scenarios in Norway	Anders H. Strømman and Troy Hawkins
Agnes Cwalina	Urban structures, building stocks, and flows of materials and construction and demolition wastes in Trondheim	Helge Brattebø
Sébastien Dente	Greenhouse Gas Emissions from Transportation Associated with French Consumption	Troy Hawkins
Michał Gryczon	Combined Life Cycle and Economic Assessment of Wood-based Bio Fuels in Norway	Anders H. Strømman
Ola Moa Gausen	A Dynamic Bioaccumulation Model for Three Key Species in the Barents Sea	Edgar Hertwich and Karin Veltman
Catherine Izard	The Anthropogenic Tin Cycle of the United States, 2005	Daniel Müller
Øystein Kostøl	Eco-efficiency of Power Generation Options at a Refinery	Edgar Hertwich
Magnus Løseth	A Model for Estimating the Global Warming Potential of the Norwegian Electricity Supply in a Life Cycle Perspective	Helge Brattebø, with Ole Jørgen Hanssen at Østfoldforskning
Sebastiano Scacchetti	Stock dynamics model for forecasting aluminum flows in the Norwegian passenger car system	Daniel Müller



In November, the students arranged a Christmas Workshop to decorate their reading room. Photo: Elin Staurem.

### Karen Elise Sundelin



Second-year master's student Karen Sundelin grew up in Kristiansand,

Norway and moved to Trondheim when she started college. She studied geography and social economics at NTNU and completed a bachelor's degree in social science. Through the course of her studies she discovered that she was interested in a career focused on issues such as climate change and nature preservation. As a result, she was excited to come across Industrial Ecology's Master of Science programme while reading through NTNU's catalogue. She was attracted to the programme that she sees as providing students with tools to discover concrete, practical solutions to complex environmental issues, and she has found that the master's degree in Industrial Ecology has given her the opportunity to

build on the knowledge she gained through her social science education.

As a social scientist, Karen admits that she found some of the MSc courses to be quite challenging at first. Concepts such as life-cycle assessment and material flow analysis were new to her because she didn't begin the programme with a technical background. However, she soon came to find those tools useful for evaluating potential solutions and policies for dealing with environmental problems. One industrial ecology course that she has particularly enjoyed is the environmental management course and she believes that what she learned there will be helpful in her future work. She hopes to work in the area of corporate social responsibility or in the Norwegian Ministry for Environmental Protection when she finishes the MSc program.

As a second-year student, Karen is busy working on her master's project this semester. She is studying the stock of aluminum

currently in use in Trondheim. This project is exciting because the data that she collects will be useful in future research done by IndEcol scientists and there are very practical, real-world applications for her work. Her work is advised by IndEcol Professor Daniel Müller. While working on her project, Karen says that she has learned about the research process and the challenges of gathering data and using new methods for analyzing complex problems. She has also learned a lot about how to organize her time well, structure a large project and meet deadlines.

In her free time, Karen enjoys singing in a choir and hanging out with other IndEcol students. When she started the programme last year she found it was easy to get to know the other students and she enjoys being part of a community of people who are interested in the same thing - finding effective solutions to environmental problems.

## Rayson Ho



Rayson Ho began his master's degree at IndEcol in September of this year. Since that time he has

been an active member of the IndEcol community by playing a key role in organizing events for the students and acting as a student representative to the IndEcol Steering Committee. We are thankful for his willingness to help strengthen the student culture in the Industrial Ecology programme, and wanted to find out more about his experiences in Norway so far.

*Where do you come from, where did you grow up? Where did you do your undergraduate education?*

I was originally born in Hong Kong, China but I moved to Canada when I was really young and have lived there for the majority of my life until recently when I took some time off and backpacked around the world for almost 2 years. I graduated from the Wilfrid Laurier University: School of Business and Economics (SBE) with an Honours Business Administration degree (with a Co-op option) in Waterloo, Ontario, Canada.

*How did you learn about NTNU's Industrial Ecology Programme? Why did you decide to do a master's degree here?*

I originally started searching on Google to find out what post-graduate programs were out there that interested me. Pretty soon, I quickly focused on environmental management related programs and NTNU's MSc in Industrial Ecology programme easily became one of the more prominent and attractive programmes

that I wanted to apply for. From an outsider's perspective, Scandinavia is perceived to be one of the most progressive regions in the world when it comes to sustainable development issues and responsibilities. The programme is well reputed, as well as NTNU itself around the world and the fact that tuition is free certainly was a bonus!

*What have you enjoyed about the program so far? Or what is your favorite part? What did you like about living in Trondheim or Norway?*

Even with my limited technical training (given my business administration background), I was able to immerse myself into more technical courses such as Life Cycle Assessment and Industrial Ecology and have really taken advantage of the new concepts and approaches that are being taught. The teachings are very interdisciplinary and have opened my eyes to the possibilities this program can bring about. The LCA course has been my favourite part of the program so far because it teaches us to calculate true cost accounting of cradle-to-grave corporate processes and products that can be applied to any industry.

The Norwegians on the whole are very nice and easy-going. Party-ing with them- they really let loose after a couple of beers, which is funny to watch sometimes! But the geography and the people are fairly similar to Canada.

*What do you hope to do with your degree when you are finished?*

*What do you think you have learned from the program so far that you will use in the future work?*

I really hope to make a difference, especially in the field of corporate waste management in South America. Backpacking through the continent, I quickly realized that any form of recycling (with the exception of metals and glass)

was severely lacking even in very modern cities like Sao Paulo, Buenos Aires and Santiago de Chile. I'm planning on writing my thesis paper on this topic.

*What do you like to do in your free time?* The advantages of living in Trondheim are that there are a lot of people into hiking, cabin trips, skiing, climbing and other outdoor activities. So on the weekends, I'm usually out doing one of those things or partying with the Norwegians and the other internationals in the city or at the student residences. I really fell in love with Brazil while I was traveling there earlier this year and I was surprised to find that NTNUI has capoeira (a Brazilian form of street fight-dance) training so I've been doing some of that as well.

*You've been involved in organizing activities for IndEcol students, can you talk a bit about that?*

Every Wednesday, there's an onsdagspilsdag for the 1st and 2nd year students to hang out over some beers. But at least once a month, we have something else set up too like poker games, movie night, cabin trips, ski trips and some big parties too of course. Also on Fridays, we get together at lunch time on campus and have some traditional porridge at the cantina. But it's been great, at least with the 1st year class. It has been one big (and at times dysfunctional) family!

In 2008, 23 students were admitted into the MSc programme, of which 12 were international students and 11 were Norwegian. 17 of the new students were female, 6 were male. Over the time it has run, the programme has admitted a 50/50 ratio of male and female students.

# POSTGRADUATE SCHOOL OF INDUSTRIAL ECOLOGY



The Postgraduate School of Industrial Ecology (PSIE) successfully completed its first series of courses in June 2008. PSIE is a project under the European Union's Marie Curie Conferences and Training Courses (Contract PSIE - MSCF-CT-2005-029529), which means that the EU financed direct participation costs of participants and part of the organizing costs.

The Industrial Ecology Programme at NTNU was the project coordinator. PSIE was a series of seven courses held in 2007 and 2008 especially designed to provide research training within the field of Industrial Ecology. The courses took place at different universities, with special focus in Central and Eastern Europe, and gathered students from many different nationalities. Each course was held over two weeks, and included both lectures and in-class group exercises. There was also a final individual project that students completed after the course. The two-week modules were intensive and gave the participants the opportunity to learn the most up-to-date research methodologies within the field.

IndEcol PhD student Raquel Santos Jorge participated in the PSIE courses and found them to be worthwhile. She says, "Having students with different backgrounds, but a shared interest in the field of industrial ecology, created a very rewarding learning experience for all of the participants."

Jan Weinzettel, a researcher at the Charles University Environment Center in Prague, participated in all the PSIE courses. He offered his reflections on the program in a recent issue of the ISIE Newsletter. It is reprinted here with his permission:

"The first series of the courses of Postgraduate School of Industrial Ecology (PSIE) has finished recently. It was closed with the course on Sustainable Consumption in Prague last June. All the courses were designed to evolve student knowledge about state-of-art ideas and techniques in industrial ecology, building up a great group of people with similar interests. Covering basic concepts through sophisticated methods, such as life cycle assessment, towards soft science in value chain management and sustainable consumption, PSIE was comparable to the general development in industrial ecology – from end-of-pipe technologies toward prevention. The closing session moved our scope more to the world of our daily life, to learn more about our decision making processes and our direct and indirect pressure on the environment.

One of the most important benefits of PSIE was that it created a

group of PhD students and young researchers, who, as I hope and believe, will keep in touch. This will enable easier cooperation between research institutes all around Europe.

Thanks to Edgar and the organization team at NTNU, I hope you will continue with PSIE also for the next generation of PhD students."

From the coordinator's perspective, PSIE was more of a drain on resources than expected. "The EU has onerous reporting requirements, and not all of those were communicated to us. Having to re-do administrative reports was no fun," says Edgar Hertwich. "On the other hand, I enjoyed the interaction with all the young bright participants, and I would be happy to teach such a course again."

IndEcol's PhD students have now requested more PSIE-style PhD courses. IndEcol is investigating options to produce new courses in collaboration with other universities in Europe. PSIE was made possible by the Marie Curie program, though a substantial portion of the organizing and administrative costs were covered by the partner universities.



Participants at the Value Chain Modelling course at the University of Surrey, UK.



## ENVIRONMENTAL MANAGEMENT AND CSR

The research group for Corporate Social Responsibility (CSR) and Environmental Management in Global Systems within the Department of Industrial Economics and Technology Management (IØT) collaborates with IndEcol on a number of projects.

Since CSR integrates social and environmental dimensions into business activities, research in this field demands a multi-disciplinary approach. Within the area of CSR, firms voluntarily accept the challenges of transparency and accountability in their reporting and external communications. Meeting these challenges requires development of new methodologies that support the assessment of their systems and reveal the potential for improvement of the systems for environ-

mental management and global production. The research group within IØT supports the Industrial Ecology Programme on these issues.

Manufacturers who produce and sell in the global marketplace are coming under increasing requirements for product documentation. These firms must be prepared to provide documentation regarding environmental impacts and quality issues. In 2008, further work has taken place on the project "Data assisted tool for sustainability product information" (DAT-SUPI). In DATSUPI, the main goal is to develop an integrated design tool based upon LCA-information and social-relevant information of furniture that helps firms address their commitments to sustainability reporting. An initial release

of the product was demonstrated to a select group of Norwegian furniture manufacturers during a seminar held in October.

A second project, C(S)R in Global Value Chains: a Conceptual and Operational Approach, also continued into 2008. In April, a seminar was held to address the question of the "Implications for CSR Practice along the Value Chain." Many of the speakers at the seminar addressed the problem of realization of CSR-practice, both in single companies and in value chains. They concluded that standardization of information for comparisons between global companies is a missing component. Likewise, stronger regulations are needed to balance the CSR proposition in global competition. This project concludes in



Group picture from CSR seminar in April 2008: (from left to right) back row – Natalia Vakar, Ottar Michelsen, Atle Midtun, Terje Skjønhal, Uno Abrahamsen, Fritz Balkau, Christian Senstad, Christofer Skaar; front row – Cecilia Haskins, Annik Magerholm Fet, Caroline Cheng, John Hermansen, Cecilie Stray, Kjetil Staalesen.



## RESEARCH

December with a closing seminar addressing practice and policy in CSR.

Christofer Skaar continued his PhD-project, which has evaluated product information and the extent it is possible to gather sufficient information about the environmental impact of the materials throughout their life cycle. In addition, the quality and the reliability of the information are evaluated, with a focus on the verification of information. Models on how to aggregate information along the value chain and how to allocate corporate information to the product level are tested based on LCA-techniques and mathematical models. Case studies have been written on the production chains of furniture and on mechanical equipment for buildings, and were published in 2008. The models used for the assessment of environmental performance have been tested for a few CSR-issues, such as working environment in the production phase of a product, and on potential health impact during the use of the products. Emission data from the finished products are gathered through laboratory tests, and will be integrated in DATSUI, described above.

Industrial ecology master's students, Caroline Cheng and Tore Søliland, are also making research contributions to a new project named Innovation in Global Maritime Production 2020 (IGLO-MP), which is led by Professor Fet of IØT. The primary value of the cooperation on these projects is that researchers from different disciplines and scientific traditions work together, which in turn generates new discourse and

research questions raised from different perspectives. They also serve to further strengthen the dialogue between academia and industry.

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See also: [www.iot.ntnu.no/csr](http://www.iot.ntnu.no/csr)

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## SCIENCE MINISTER CONGRATULATES NTNU FOR SUSTAINABILITY EXCELLENCE



The Norwegian Minister for Science and Higher Education, Tora Aasland. Photo: Stig Weston.

The Norwegian Minister for Science and Higher Education, Tora Aasland, congratulated NTNU for being ranked No.1 in Europe in Engineering Education for Sustainable Development by the Engineering Education Observatory, ahead of the Royal Institute

for Technology KTH in Sweden. The ranking was based on technical universities' general efforts in introduction sustainability in engineering education and their leadership in introducing specialized programs. The Minister took time to talk to two students about their studies.

Prorektor Julie Feilberg, the chair of the Department of Hydraulic and Environmental Engineering Helge Brattebø, and IndEcol director Edgar Hertwich had the opportunity to present NTNU's activities in engineering education for sustainability to the Minister, and we received a set of potted plants as recognition from her. The honor is being shared with a large number of faculty and staff members who worked over many years to create an attractive educational offering.

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## CARBON NEUTRAL RESIDENCES

With IndEcol support, PhD student Stig Larssæther initiated a process to develop a climate-friendly building project at Brøseth, Trondheim. With support of the research council, NTNU and Sintef researchers will assist in the development process, focusing on passive house technology, innovative water solutions, gardening, climate-friendly lifestyles, and user involvement.

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## SUSTAINABLE INFRASTRUCTURE

Sustainable infrastructure is a long term strategic research initiative at the Faculty of Engineering Science and Technology. Sustainable infrastructure has a long term research focus on both the adaption of buildings and infrastructure to climate change, as well as the reduction of environmental impacts from the built environment.

Such a long time commitment to research on sustainable infrastructure is of utmost importance if society is to move towards sustainability, since buildings and infrastructure have such a big impact on the environment due to their huge demand for energy and materials both in construction and throughout their entire lifetime. Buildings and infrastructure are also unique when compared to other products due to their very long service life. Thus, reductions on environmental impacts from this sector will have a tremendous positive impact on the long term development of the climate.

The research is organized around the thematic areas: "codes and regulations", "climate change and consequences", "risk, vulnerability and safety", "construction and management" and "resources and environment (Industrial Ecology)." The research program has several sub-projects at the three departments in civil engineering, and besides the contributions of the academic staff, to date 10 phd and 2 post-doctoral scholars are financed through this initiative. There are two groups from the Industrial Ecology Programme involved in "Sustainable Infrastructure."

### **The Waste Management and Industrial Ecology research group**

The Waste Management and Industrial Ecology research group, in the Department of Hydraulic and Environmental Engineering, centres its research on resource consumption (materials and energy) and waste generation in various sectors, including the construction industry and society's built environment.

The research is managed by Professor Helge Brattebø and Professor Daniel Müller, and builds on dynamic analysis of important built environment stocks and flows, such as buildings, water and wastewater networks, and bridges and roads, as well as the overall urban metabolism of material, energy and waste flows. The philosophy is that built environment stocks on the one side provide service and function to the population and on the other side pull on resource inflows and push on waste and emission outflows, in a life cycle perspective. Given systems (urban and/or rural) and their technological sub-systems are examined and modelled in a systematic way by use of material flow analysis (MFA), life cycle assessment (LCA) and life cycle costing (LCC) methods, and brought into a dynamic framework by use of empirical analysis of past trends and scenario analysis for future trends. The aim is to develop a combined theoretical/methodological and empirical approach, and develop improved analytical integrated modelling methods, contributing to better long term understanding of sustainability development patterns and how given systems can be improved by influencing the critical

parameters that determine the development and performance of the systems, such as buildings, wastewater networks and bridges.

The research at present includes four sub-projects, each involving one Ph.D. candidate: Håvard Bergsdal is exploring the use of dynamic MFA for understanding long term changes in the Norwegian housing stock, regarding stocks and flows of useful floor area, major materials, waste generation and PCB. Venkatesh Govindarajan is studying the dynamics of stocks and flows in water and wastewater infrastructure, the ageing phenomena in such systems, and life cycle economic and environmental performance of asset management strategies. Johanne Hammervold develops LCA models for bridge design comparison, and LCA models for water and wastewater networks, and will now start examining road system infrastructure by LCA methodology. And Nina Holck Sandberg examines the dynamic energy consumption flows to the Norwegian building stock system, and their LCC and LCA performance, by historic data and scenario modeling of policy strategies towards 2050.

### **The Building and Material Technology research group**

The Building and Material Technology research group, in the Department of Civil and Transport Engineering, is involved in sustainable infrastructure by the commitment of Prof. Per Jostein Hovde and Assoc. Prof. Rolf André Bohne. In addition to the administration of the overall projects, they are running three sub-projects,

and are also involved in several European activities on the sustainability of the AEC- industry.

The three sub-projects, have now recruited two post-doctoral scholars and one Ph.D. candidate, and will be fully operational in early 2009. The three projects are:

- Key areas and existing knowledge base for a sustainable infrastructure (1 Post-doc): The objective is to prepare a sound state-of-the-art report regarding key areas and topics that will form a knowledge base for future work towards a more sustainable infrastructure.

- Indicators for a sustainable infrastructure (1 Ph.D.): The objective is to establish a specific list of indicators that can be applied for measurement of sustainability in the various stages of the life cycle of a specific infrastructure. The indicators should as far as possible express quantitative measures of the sustainability of the infrastructure.

- LCA and LCC of infrastructure (1 Post-doc): The objective is to establish procedures for LCA and LCC of specific parts of the infrastructure, collection of input data and documentation of demonstration cases

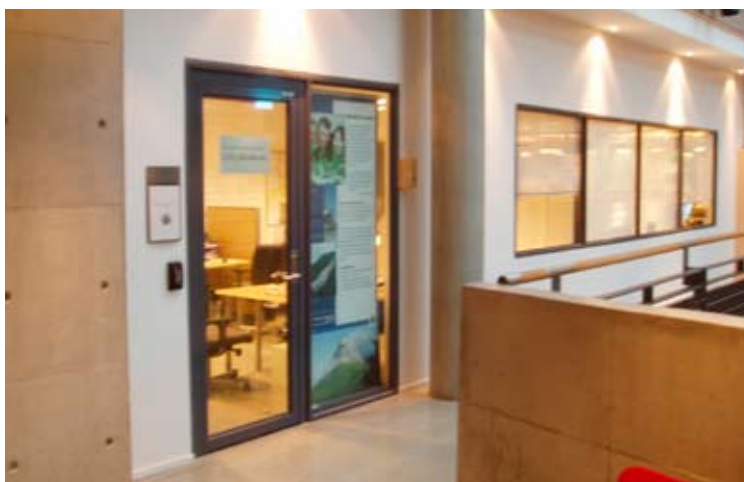
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## ENVIRONMENTAL ASSESSMENT OF BIOFUELS



IndEcol offices and LCA-lab. Photo: Anders Strømman.

The development of more sustainable transport poses major challenges for both developed and developing economies. The path towards sustainable transportation will require a multitude of strategies consisting of continued technological improvements in powertrain efficiencies, vehicle design, and ultimately a shift away from carbon-intensive fossil fuels. Alternative fuels such as biofuels made from renewable resources offer appealing short and mid-term climate change mitigation opportunities because they, as an energy carrier, are compatible with existing engine technologies and transport infrastructure.

Researchers at the Program for Industrial Ecology at NTNU are currently active in sustainable transport research. The core of recent research involves the application of life cycle assessment (LCA) to evaluate the environmental impacts of future transport technologies, including biofuels, for guiding responsible decision-making regarding those biofuels

which are being considered in Norway.

Two master students at the Industrial Ecology Program - Michal Gryzcon and Ryan Bright - investigated the environmental implications of the use of Norwegian wood resources for the production of 2nd generation biofuels during the final year of their master studies. Michal explored the techno-economic aspects of future wood-ethanol production in Norway, and Ryan performed resource assessments and LCA-based scenario analyses of future wood-biofuel (both green diesel and ethanol) production and consumption in Norway. Industrial Ecology is further pursuing biofuel research.

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## MATERIAL FLOW ANALYSIS RESEARCH GROUP

The MFA group focuses its research around the following overarching questions:

1. How can we describe the metabolism of societies (stocks and flows and their uncertainties)?
2. How does the societal metabolism evolve over time; and what are its key drivers and control variables (dynamics)?
3. What are its impacts on environment, resource supply security, and geopolitics?
4. What are potentials and limits for re-designing the societal metabolism in order to provide a higher quality of life while reducing the negative impacts?

We try to provide answers to these questions by focusing on two complementary topics: urban systems of multiple resources and global multi-regional systems of individual resources. On the urban scale, we analyze the evolution of built environment systems (mainly buildings and infrastructures) as the quantitatively most important resource users and reservoirs for future secondary resource supply (exploration for urban mining). For more information on MFA research on the urban scale, see sections "Sustainable Infrastructures" and "Waste Management and Industrial Ecology research group." Cities are the most important engines for anthropogenic material and energy cycles, however, potential resource constraints or geopolitical dependencies cannot be assessed on the local scale and require a global, multi-regional (or multi-level) approach that links the cities as the locations of resource consumption with the rural areas that provide the primary resources.

The study of global multi-regional systems uses iron/steel and aluminium as case studies. For these

metals, we focus on two central topics:

a) Dynamics of resource cycles: In the "dynamics" topic, we analyze the historic evolution of resource cycles in various world regions and use the insights from this to build long-term scenarios for the future. The goal is to estimate future long-term raw material demand and scrap availability and quality in various world regions. This information is used to analyze implications for mining primary and secondary resources and to support the design of more efficient recycling strategies.

b) Multi-level resource cycles with explicit analysis of trade: Raw material cycles are increasingly global in nature, with mining, refining, product manufacture, use, and recycling or disposal taking place in different locations. As a consequence, emissions (e.g., carbon dioxide emissions) and environmental impacts (e.g., climate change) often occur in various places far away from consumption of the final products. Tougher environmental regulation in individual countries does not necessarily lead to a reduction in overall emissions, but often stimulates the move of manufacturing sites, jobs, and emissions to other countries with lower standards. The design of alternative regulations that accounts for these "leaking" effects (e.g., sectoral agreements) needs to be based on an adequate understanding of global multi-level resource cycles that link resource cycles for individual countries with international trade of products along the material cycles (e.g., ore, refined metal, parts, final products, or scrap). In the "multi-level" topic, we analyze the global supply chains for individual resources and link this

information with energy use and emissions in various stages of the cycles.

*External collaboration and visitors:* Michael GERST finished his Ph.D. thesis at Yale University (USA) under the title "Global scenarios of the anthropogenic copper system in the 21st century". Daniel Mueller, co-supervisor in this thesis, attended Mike's Ph.D. defense in August 2008.

Jason RAUCH, Ph.D. student at Yale University (USA), continued his work on global anthrobiogeochemical metal cycles and their spatially explicit visualization. Daniel Mueller, co-supervisor in this thesis, visited Jason in August 2008.

Mingming HU, Ph.D. student from Leiden University (Netherlands) and Chongqing University (China), visited us in October / November 2008 to develop a dynamic model for the urban and rural dwelling stocks in China. This model will be extended to include iron and steel (collaboration with Stefan Pauliuk).

Anne BØEN, Ph.D. student at Bioforsk and the University of Life Sciences in Ås (Norway), works with us on the development of an MFA model for the Norwegian phosphorus cycle. Daniel Mueller, co-supervisor in this thesis, visited Anne in April 2008, and Anne visited us in November 2008.

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# ECODESIGN AND INDUSTRIAL ECOLOGY

Industrial Ecology, both as a scientific discipline and as a topic for education, builds on various social and engineering sciences—so does ecodesign, or sustainable product innovation as some prefer to refer to it. Although it may seem to both in- and outsiders that IndEcol heavily draws on mathematical modeling of material stocks and flows and their environmental impacts, a lot of research is done within our program to support national and international sustainability goals from various scientific perspectives. At IndEcol, we try to provide our students with all of these perspectives, including the role of design in sustainability research. This means, for example, that IndEcol staff teach design students about environmental assessment methodology, and that in return, industrial ecology students learn about application of various environmental assessment methods in a product design context.

To explore where insight and knowledge about design and industrial ecology can result in synergies, IndEcol students are challenged to participate in design courses such as Strategic Design, and Ecodesign. In the past years, several students have taken on this challenge which has resulted

in cooperation between design and IndEcol students in various types of group work. This includes the evaluation and redesign of consumer electronics, where students have explored how the price, quality and environmental impact of products are interconnected, and the design of eco-board games aimed at increasing awareness around environmental issues among employees involved in industrial product development. Students benefit from working in interdisciplinary teams not only by sharing insights on specific disciplinary knowledge but also by experiencing different ways of working on a project. The creative nature of design students and the analytical nature of industrial ecology students usually complement each other well.

IndEcol students are also challenged to work on individual, research-oriented assignments that explore the link between design and industrial ecology. This, for example, resulted in a conference contribution that reviewed LCA utility in Eco-Design from an Engineer, Designer and LCA Specialist perspective. The review illustrates that in today's design practice, LCA is of limited utility for several practical reasons, and yet, conversely, it is also an

indispensable tool to draw up a precise map of the environmental effects and impacts generated by a product. This contributes to the LCA-ecodesign paradox which implies the need for continued research on simplifying and refining a more designer-friendly LCA-based tool that

does not require additional time and/or resources to interpret, and which is tailored to meet a design team's specific needs across varying industries.

Such insights are valuable input for research that is of interest to both the design and industrial ecology domains, and we make an effort to get such projects off the ground, even if they are difficult to fund by industrial partners as benefits are often not apparent immediately.

Other joint research initiatives focus on including consumer perspectives in the industrial ecology domain. User-centered design is one of the focal research topics within the Institute of Product Design, and in the last year, IPD's PhD student Ida Nilstad Pettersen has been cooperating with various IndEcol researchers to explore the role of user-centered design strategies in stimulating sustainable patterns of consumption such as through climate calculators and expert systems. This is essential when we want to translate important IndEcol research into practical applications that individuals can and want to use. After all, insight into how humans think and act are key to change user behaviour for the sustainable better, just as research in the political and industrial domain are key to support and improve policies and industrial activities related to sustainability. We can consider ourselves lucky to have such a multidisciplinary research and education community at NTNU; and it is our responsibility to make use of this community wherever we can!

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Ecodesign students playing EcoCalypso - their own design eco-board game. Photo: Casper Boks

## INTERNATIONAL RESOURCE PANEL TO BUILD ON INDECOL RESEARCH

In November 2007, the United Nations Environment Programme (UNEP) launched the International Panel on Sustainable Resource Management (Resource Panel). The overall objective of the Panel is to provide independent scientific assessments on the environmental impacts from the use of resources, both renewable and non-renewable, over the full life cycle.

The work of the Panel contributes to a better understanding of how to reduce these impacts by decoupling resource use and environmental impact from economic growth. It takes into account economic development, resource productivity and supply security issues. The panel is co-chaired by Ernst Ulrich von Weizsäcker, Dean of the Bren School of the Environment at UC Santa Barbara, and Ismael Serageldin, the World Bank's first vice president

on sustainable development and now Director of the Library of Alexandria, Egypt.

Professor Edgar Hertwich leads the working group on the prioritization of products and resources from an environmental sustainability point of view. This working group will analyze product groups, consumption categories, and materials in order to identify those with the largest environmental impacts. This work is meant to help Integrated Product Policy and related efforts in tackling the biggest issues first. The work builds on IndEcol research on the environmental impacts of consumption and emissions embodied in trade. Other Panel studies address the stocks and flows of metals, the environmental impact of biofuels, and decoupling. With Marina Fischer-Kowalski, Tom Graedel, Yuichi Moriguchi, and Stefan Bringezu, the industri-

al ecology community is strongly represented on the Panel. IndEcol professor Daniel Müller is contributing to the working group on metals, where the in-use stock of metals and metals recycling are important considerations.

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### MONGSTAD PILOT PROJECT CONCLUDED

NTNU researchers have investigated opportunities for increased resource productivity at Statoil's refinery Mongstad, Western Norway. The work at IndEcol has focused on new processes that could be integrated with existing processes, primarily synfuel production from biomass and coal, electricity production with carbon capture and storage, and fish farming.

In the latest phase, we have focused on environmental aspects of the alternatives. MSc student Øystein Kostøl has evaluated different configurations, and Post-Doc Karin Veltman has evaluated the toxic impacts from emission specific to carbon capture plants. The project is presented in the IndEcol newsletter, Summer 2008. We would like to thank our partners at Statoil Mongstad, especially Signy Midtbø Riisnes, for the cooperation!



Stefan Bringezu, Edgar Hertwich, Anna Bella Siriban-Manalang, Lea Kauppi, Mark Swilling and Marina Fischer-Kowalski.



## SPOTLIGHT ON: RYAN BRIGHT



IndEcol PhD student Ryan Bright started off his Ph.D. career with a bang. Soon after finishing his MSc in Industrial Ecology

in June 2008, Ryan presented the results from his master's thesis at the Gordon Research Conference at Colby-Sawyer College in New Hampshire, USA. Ryan was awarded the Best Poster Award for his poster 'Hybrid Life Cycle Assessment of Wood-based Biofuel Production and Consumption Scenarios in Norway'. We asked Ryan to talk a bit about his decision to study and work in Norway.

*What attracted you to Norway and the MSc program in Industrial Ecology?*

The reputation of the Industrial Ecology MSc program at NTNU is what attracted me to Norway. Specifically, the more comprehensive two-year curriculum and the well-established and distinguished research community here at IndEcol. At the time of application, it was not possible to obtain an MSc (or equivalent) in the field of Industrial Ecology at a U.S. academic institution (that may still be the case today, I'm not sure).

*What do you like most about living in Trondheim, or in Norway in general?*

The thing I enjoy most about living in Trondheim is the fact that I don't need and am not dependent on owning a car for mobility!! One of the things I enjoy most about living in Norway, in general, is a social environment where people tend to generally appreciate the simpler joys of life and aren't quite

as fixated on equating material wealth as a measure of personal happiness. I also enjoy living in a culture where most people are very keen about getting out and enjoying nature through outdoor recreation, and because of this, I think most Norwegians generally have a more intrinsic appreciation of, and fonder respect for, the natural world. Or maybe it's the other way around! Anyhow, it's nice being able to share similar values with the masses.

*What topic did you research for your master's thesis?*

I investigated the potential for Norway to produce liquid biofuels made from forest resources by conducting resource assessments and analyzing the environmental performances of systems utilizing those resources for the production of more sustainable liquid transport fuels. For the environmental analyses part, I applied core methods and analytical tools of industrial ecology, such as LCA (life cycle assessment), EIOA (environmental input-output analysis), and hybrid LCA (an integration of the former and latter).

*Why did you decide to pursue a PhD at IndEcol?*

I wanted to pursue a PhD at IndEcol primarily because I was given the opportunity to research and work with issues that I enjoy and care about, and also because I wanted to be a part of an evolving and distinguished industrial ecology program and research community here at NTNU. Also, I feel as though I'm just not ready for a regular 9-5 job in industry -- I still have a lot of learning to do!

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## ONE PLANET ECONOMY NETWORK EUROPE (OPEN:EU)

IndEcol and Stockholm Environment Institute (SEI) will be the core partners of WWF UK in an EU-funded project to develop an advanced environmental footprinting tool, if negotiations with the European Commission are completed successfully. The aim is to provide better information about the environmental consequences of local planning decisions to decision makers. Environmental consequences will be measured in terms of the ecological, carbon and water footprints. The tool will be an extension of SEI's Resource and Energy Analysis Programme (REAP) currently used widely in the UK.

"This collaboration with WWF is an excellent opportunity for us to bring our research advances to bear on problems facing local and regional decision-makers. These advances include a global input-output database that we are building in another EU project, EXIOPOL, and algorithms for the analysis of production-consumption networks," says IndEcol PostDoc Troy Hawkins, who co-authored the proposal.

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## CARBON EMBODIED IN TRADE

As global trade volumes increase faster than any other macroeconomic variables, the effect of trade on global greenhouse gas emissions is of increasing interest. Metals industries, but also manufacturing companies, are concerned that a tough national climate policy will hurt their international competitiveness. They use concerns about “carbon leakage” – the movement of emissions-intensive production to countries without emissions constraints – as a powerful argument in their lobbying against such policies. The lobbying has been effective in delaying the auctioning of emissions rights under the EU’s Emissions Trading System (ETS). How important, however, is the embodiment of CO<sub>2</sub> emissions in trade really? And is there a legitimate concern about “carbon leakage”? What can be done about it?

In a series of papers, IndEcol researchers Glen Peters, Edgar Hertwich, and collaborators have investigated these questions. They have shown that, in 2001, the production of internationally traded goods caused 22% of global CO<sub>2</sub> emissions. Moreover, the goods imported by most developed countries cause more CO<sub>2</sub> in their production than the goods exported by these countries. On

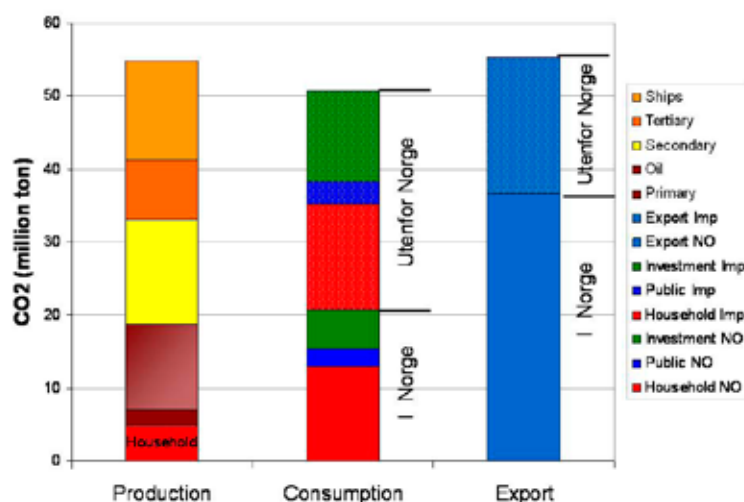
the global level, the net imbalance between developed and developing countries corresponds to 5% of CO<sub>2</sub> emissions. That means that the carbon footprint of developed countries is larger than the national emissions inventories indicate. The countries that have a lot of CO<sub>2</sub> embodied in exports are either resource-intensive primary producers, such as Australia, Russia, South Africa, and Norway, or the global centers of manufacturing, such as China and India. These numbers are significant as they are in the same order of magnitude as emissions reductions planned under the Kyoto protocol. It is, however, especially the dynamic development that presents a cause for concern.

In a series of reports, IndEcol worked with WWF on detailing the European and national implications of emissions embodied in trade and climate policy. The report for WWF Norway documents that emissions in Norway’s imports have grown by 33% from 2001 to 2006, to 39 MtCO<sub>2</sub>. In comparison, Norway’s territorial emissions have stayed nearly constant, around 55-57 Mt. The emissions embodied in imports from developing countries are growing fastest; they have increased by 69%. This implies that Norway’s carbon footprint keeps

growing in spite of apparently constant national emissions – we are just outsourcing the pollution to poorer countries.

These trends are confirmed by studies on China’s rapidly growing emissions. According to official statistics, China’s CO<sub>2</sub> emissions almost doubled in the period from 2002 to 2007, a rapid acceleration in the pace of growth that has taken the entire world by surprise and that has put China ahead of the US as the world’s largest polluter. A new paper by Weber, Peters, Guan and Hubacek shows that while in 1987 only 12% of China’s emissions were due to the production for export, that share rose to 21% in 2002 and 33% in 2005. The production of China’s exports was in 2005 responsible for 1.67 GtCO<sub>2</sub>, a total of 6% of global CO<sub>2</sub> emissions!

In a commentary in NATURE Reports Climate Change, Peters and Hertwich argued that emissions embodied in trade are too important to be ignored in the future. Rather than seeing it as a problem, we should see them as an opportunity. If energy-intensive production shifts to where carbon-free energy can be produced cheaply, trade in energy-intensive products can contribute to mitigating climate change.



## VESTED INTERESTS VERSUS NEW ENERGY



This has been my final year at Industrial Ecology. As of late November, I'm leaving Trondheim

for a two-year post-doctoral stipend at the School of Policy Studies at Kwansei Gakuin University in Sanda, Japan, on the outskirts of Kobe. At KGU I will keep working at the same issues that I have worked on for two years here in Trondheim, and the work on renewable technology and industry that I have already completed here will find its way into a book that I hope to produce within the next two years. This will be a book highlighting the symbiosis between energy and industry and the politics that go into creating conditions that are conducive to structural economic change within both energy and industry. The book will be a kind of history of energy, looking at energy and industry over the past 250 years, but from the perspective of the political economy.

In my book *Governance, Growth and Global Leadership*, I observed that in an industrially successful country, vested interests over time may easily grow so strong and influential that they, in the long term, damage the country's ability to structurally transform its economy. Instead, the country stays with industries and industrial activities that become gradually ever more obsolete. My present project suggests that this will often be even more relevant within the energy area. Energy companies have often developed into industrial giants and massive sums of money have been in-

vested in infrastructures that can not be easily upgraded or transformed. Hence, the potential for vested interests to influence politics may actually be even greater in the energy area than within traditional industry. That also means that one cannot take for granted that the economy will simply switch from one source of energy to another just because there is a (potentially better) alternative out there. Instead, there is likely to be a lot of politics involved and a serious risk of lock-in and path-dependencies due to the political and economic influence of the already existing energy actors in the economy.

This also means that part of the fall of this year has gone into rethinking my present project, which focuses on renewable technologies and industries in the present/near-future only, and on how it can be transformed into the above mentioned project. Hence, one article outlining the general project and offering some tentative and illustrative evidence to demonstrate the fruitfulness of the approach is close to completion, and will be submitted for publication before the end of the year, as well as being presented at the ISA conference in New York in February.

Earlier this year, an article on renewable energy policies in Norway and Denmark was submitted for publication. In addition, a book chapter on renewable energy policies and vested interests in Norway was completed and is scheduled to be published either late this year or early next year in a book edited by Gunnar Fermand called *The Political Economy of Energy in Europe* (working title). A report on Norwegian industrial policy, focusing in particular on

renewables was written for the think-tank LibLab. In cooperation with Innovation Norway and Kaare Gether, I have also completed a report on Norway-China relations with an assessment of Chinese energy policies and policy recommendations about what Norway's strategy should be with respect to Chinese energy policies and to what extent and in what way Norway should be able to assist. Finally, a chapter of mine on North-South relations was published in Rafael Reuveny and William Thompson's edited book *North and South in the World Political Economy* this summer, and in the 2009.2 edition, the *Review of International Political Economy* will publish my article entitled "Mancur Olson and Structural Economic Change". It is already available electronically.

It has been a good two years for me at the Industrial Ecology Programme. In many ways, I feel that my stay has not yet ended, as I will keep working on the many of the same problems and projects whilst in Japan. I very much hope that I have been able to contribute to the Programme whilst here, and that my contribution to the Programme has not yet come to an end even as I am now about to leave.

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## NEW COMPANY FOUNDED: MiSA

Emboldened by the favorable business climate for LCA and environmental systems analysis, IndEcol alumni Johan Pettersen (PhD 2007) and Christian Solli (MSc 2004) decided to start their own company. They founded MiSA AS in the fall of 2007, together with IndEcol Professor Edgar Hertwich. MiSA is a research and consultancy company that applies Industrial Ecology tools such as life cycle assessment and input-output analysis to a wide range of business applications.

So far, business has started well, even if Johan and Christian are not yet fully booked out. Since starting the business over a year ago, MiSA has been approached by a steady stream of companies that are concerned about the environmental impacts of their products. In contrast to many environmental assessments that consider only one aspect of the problem, MiSA makes use of the systems thinking approaches taught and developed in the Industrial Ecology Programme. This means considering multiple environmental issues and mechanisms, in the context of complex business and societal environments.

With offices located in the Innovation Center Gløshaugen, a business incubation center on NTNU's main campus, MiSA is able to maintain strong relationships with IndEcol researchers. Johan and Christian regularly serve as guest lecturers and graders for IndEcol courses and hope to offer students opportunities to work on short-term projects with MiSA in the near future. These internships would provide students with experience working at the interface of business and the environment, and could eventually lead to employment opportunities with

the company.

Starting a business may sound like a big risk, and it is a task that certainly can be challenging at times. However, Johan and Christian have found that they enjoy many of the aspects of running their own business. "When you start a business you have to learn to do everything yourself, from purchasing supplies to setting up pensions," Christian tells me, "You learn how the system works, and it's fun." A difference between working at MiSA and their previous work at the university is that at MiSA Johan has found that "you get to decide for yourself if you want to do something or not. You can decide to join in on a research project or not, and you can determine the scope of the projects you are involved in."

In starting their own business, they have made use of the many resources available to entrepreneurs. The website Bedin.no, a service sponsored by the Norwegian Ministry of Trade and Industry, provides a wealth of information for start-up businesses and

has been very helpful for MiSA's founders. Christian and Johan have also benefitted from their relationship with the Innovation Center. By locating their offices in the Center, they have access to basic office necessities such as a copier and fax machine, along with meeting space and computer support. In addition, through the Innovation Center they were able to find an accountant to help manage MiSA's financial issues.

MiSA also recently received a development grant from Innovation Norway. The grant will be used to complete an internal development project, together with new partner and IndEcol PhD student Hogne Nersund Larsen.

With strong scientific backgrounds, and access to the latest research in the field, MiSA's founders should be well positioned to become leaders in providing high quality environmental analysis to the Scandinavian business community.

Visit: [www.misa.no](http://www.misa.no)



Christian Solli and Johan Pettersen in their office at Perleporten ("The Pearly gates").

## ROLF ANDRÉ BOHNE NEW FACULTY MEMBER



Industrial Ecology welcomes Rolf André Bohne to the faculty of NTNU. In August 2008, Rolf was promoted to an Associate Professor position with NTNU's Department of Civil and Transport Engineering, in the Building and Material Technology research group. He recently completed a Post-Doctoral Fellowship with the same group.

This new phase in Rolf's career is a continuation of his longstanding relationship with NTNU and the Industrial Ecology Programme. After completing his master's degree in microbiology at the University of Bergen in 1993, Rolf began working in the NTH (now NTNU) Department of Hydraulic and Environmental Engineering as a researcher. Through the course of this work it became clear to him that he has a passion for improving society's understanding of environmental problems and their solutions. He sees civil engineering as a natural place to start. He came to realize that how we construct buildings and the kinds of materials and energy they use can have a big impact on the environment. As a result, he decided that it made sense to focus his efforts there.

In 2005, Rolf finished a Ph.D. related to the recycling of demoli-

tion waste with his advisor, IndEcol professor Helge Brattebø. It should be noted that Rolf holds the unique distinction of being the first person to ever receive a degree entitled Ph.D. in Industrial Ecology. Others had studied Industrial Ecology before him, but he was the first to earn a doctoral degree with that title, after the first Ph.D. program in Industrial Ecology was created at NTNU.

Rolf continues to be closely associated with IndEcol researchers in his new position. With Professors Helge Brattebø and Daniel Müller, and IndEcol Ph.D. student Håvard Bergsdal, Rolf is contributing to a project that examines the material flows of the built environment. He is also responsible for coordinating and team-teaching a course on building materials. Rolf uses principles from Industrial Ecology every day and sees it as a nice framework for thinking about issues related to Sustainable Infrastructure. "It gives us a birds-eye perspective on environmental problems, which is really helpful."

Rolf's primary responsibilities involve coordinating the Sustainable Infrastructure Project at NTNU. This exciting project is relatively new, but it continues to gain momentum as it is a long-term strategic research area for NTNU's IVT faculty. Considering that the construction industry and the resulting built environment accounts for nearly 40% of the materials and energy used in the world, the effects that improvements made in that sector can have are huge! The fact that buildings and infrastructure have such a long lifetime, policies designed to encourage development to proceed in a more sustainable way can have an impact for the next 100 years.

As part of his work with the Sustainable Infrastructure Project, Rolf is also involved in a European project, SB Alliance, designing a tool that will be used in the environmental assessment of buildings for the European market, similar in some ways to the LEAD certification process now used in the United States. As Rolf says, "We need better tools in order to do the right things, and a good tool is a way to transfer the knowledge from academia to industry. It has been interesting to see that what we have been saying in academia for the last 10 years is now starting to spread to industry."

One big challenge that Rolf faces when working on these issues is that almost 95% of the construction industry is dominated by small businesses. So, while large corporations can afford to fund research projects of relevance to them, small businesses have trouble getting access to quality research because of a lack of funding for projects that focus on their issues. For this reason, the fact that the Norwegian Research Council is starting to fund projects related to the development of sustainable infrastructure is critical, and marks an important change. It also means that this is an exciting time for Rolf to be on the forefront of this research area. To help deal with the growing workload, several new Ph.D. and Post-Doc positions have been created and more are coming in the near future.

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See: [www.ntnu.no/sustainability](http://www.ntnu.no/sustainability)

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