

Annual Report 2010



NTNU
Norwegian University of
Science and Technology



Will we build a green economy?

What a difference a year makes! In 2009, the public was concerned with keeping economic activity up, ready to spend uncounted billions. For environmental protection, the chance was to capture part of the stimulus packages to invest in insulating houses, building railways and renewable power facilities, and supporting research and development of clean technologies. The Green Economy became popular overnight. In 2010, we realized that even governments cannot keep on spending more than

they earn. Public purses are being tightened. In this climate, how can we ensure continued support for the Green Economy? In my opinion, this should not be difficult: The gigantic bubble that built up 2000-2007 was based on inflating real estate prices driving excessive consumer spending. There is really no way to go back to this. There is no real shortage of capital in our economies – quite the opposite. What we need is an investment climate in which money flows to those investments that produce real returns, taking into account social costs that today sadly are still externalized. Many such investments will be green investments: insulating your house or flat and buying a more efficient heating system for individual households; development of resource-efficient, low-carbon products and services for industry; environmentally friendly infrastructure, education and research for governments. These investments have the real chance to improve our lives in the long run and to save-guard the future of our children. It is just not sure that the public will go that way, or will we act again as if it was 2000? We cannot afford another 00's, economically or environmentally!

In the situation we are in, I would argue the glass is half-full. Much is happening already. The EU has declared resource efficiency as one of its 4 cornerstone initiatives, and we have been invited to provide ideas and concepts. The Technoport conference series in Trondheim has "Smart technology for a green economy" as theme, and you will soon see videos of industrial ecologists featured on technoport.no. The building and construction industry is suddenly interested in environmental aspects of buildings and adopting passive-house standards more quickly than anybody had expected. When I started my review of this field for the Global Energy Assessment in early 2009, there was really not much literature I could find. After the review process, I had to completely rewrite my contribution to take into account of all the studies that had been published in just a year. NTNU has contributed early and is now developing more competence in this area.

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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 2010, 16 Msc degrees were awarded and 1 Master of Technology (MT) student completed a thesis at IndEcol. 21 new MSc students and 4 MT student were admitted. During 2010, 3 dissertations were successfully defended. 25 PhD students, 7 Post Docs and 2 Research Assistants were affiliated with IndEcol. 6 books, 15 book chapter, 39 journal papers, and 1 IndEcol report were published.

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

Student representatives in 2010:

Marina Magerøy and Tobin Rist

PhD/PostDoc representative:

Stefan Pauliuk

PEOPLE NEWS

Elin Matthiassen left her position as coordinator of the Industrial Ecology Programme in December after 9 years. Elin has made important contributions to the development and implementation of the international MSc programme and has put considerable effort into our web pages and this annual report. Elin has a keen interest in photography and graphical design, as readers of previous editions of our annual report can attest. She will now further pursue this interest, working with web site design and other graphical design services in Sortland, Vesterålen, Northern Norway. We would like to thank Elin Matthiassen for her efforts and dedication and wish her good luck for her future!

IndEcol welcomes **Ottar Michelsen** as programme coordinator. Ottar has been trained as a biologist and has a PhD in Environmental Health & Safety from NTNU. Ottar has worked on the implementation of environmental management and environmental product declarations, on life-cycle assessment of wood and furniture production, and recently on bioenergy. Ottar also maintains an interest in biology and ecology. Ottar's responsibilities will be overall program coordination with a focus on the scientific management. Ottar will continue to make active research contributions. IndEcol welcomes Ottar to his new position!

Troy Hawkins has returned to the United States after more than 3 years as PostDoc and researcher at IndEcol. Troy has made important contributions to building of a global multiregional input-output database in the EXIOPOL project, contributed to fundraising, and conducted research on the environmental implications of electric cars. Troy joins the US Environmental Protection Agency in Cincinnati, Ohio as a senior researcher.

Congratulation to Post Doc **Richard Wood** and his wife Lauren with their baby boy in November 2010.

Carmen Gueterres Moles has joined the IndEcol staff as a researcher. Carmen has a PhD in chemical engineering from the Spanish National Research Council, with a focus on mathematical modeling. She has worked as a Post-Doc at Unilever R&D in the Netherlands and as a researcher at ABB in Oslo. She is currently contributing to the PROSUITE project, on the prospective sustainability assessment of the widespread adoption of novel technologies.

Jan Weinzettel has joined the IndEcol staff as a PostDoc after visiting us as a PhD student in 2007 and attending the Postgraduate School of Industrial Ecology. Jan currently works on the One Planet Economy Network (OPEN:EU) project developing a tool for the evaluation of the footprint family of indicators, comprised of the carbon, water and ecological footprint. Jan has a PhD in electrical engineering from the Technical University in Prague and has been a researcher at the Charles University Environment Centre.

Thomas Gibon joins IndEcol as researcher as of January 2011. Thomas has worked at BIO-Intelligence Service, a Paris-based LCA consultant, since graduating from IndEcol MSc program in summer 2009.

Edgar Hertwich and **Glen Peters** have received the Best Environmental Policy Paper award of Environmental Science & Technology (ES&T) for their paper, "The carbon footprint of nations". The paper has also been discussed as a highly downloaded paper by the journal NATURE. Edgar has since been appointed member of the editorial advisory board of ES&T. ES&T is the most important journal in the environmental science and environmental technology categories in terms of number of papers and citations, and is among the highest ranked in terms of impact points.

PhD student **Hogne Nersund Larsen** has received the best poster award for his analysis of the Carbon Footprint of NTNU at the ERSCP-EMSU 2010 conference. This work was carried out in

his function as consultant at MiSA as, applying a methodology which he developed during this PhD study. The conference addresses sustainable consumption and production as well as the sustainable management of universities. We congratulate to the prize!

PhD students **Bhawna Singh, Bertha Maya Sopha and Hogne Nersund Larsen** have submitted their PhD theses in December 2010. The PhD defenses are scheduled for early March 2011. We wish good luck with the completion of their studies.

Tao Wang has returned to China after a post-doc of 1 year at IndEcol@IVM. Tao has made important contributions to the global metal cycle projects (iron, aluminium, cadmium) and the development of the GAIA database, and he conducted research on the iron and steel use and recycling in China and India, in particular related to scenarios for the passenger cars penetration. Tao joined the Department of Environmental Science and Engineering at Tsinghua University in Beijing.

Ni Made Dhaniati has joined IndEcol@IVM in the fall of 2010 as a part-time research assistant. Made has graduated from the IndEcol MSc programme in summer 2010 and she is currently working on a publication of her thesis on the direct energy demand of the vehicle stock in China.

Last but not least, IndEcol welcomes **Dr. Arnold Tukker**, a well-known specialist with a broad expertise ranging from sustainable consumption and innovation to environmental modeling and assessment. Continuing at his employer, the Dutch research organization TNO, he joined the Department of Product Design and the Industrial Ecology Programme as a Professor II in a 20% position. Arnold's job will be to deploy his expertise and experience in streamlining joint research projects, contribute with research funding applications, and providing co-supervision to PhD students.

SYMBIOSIS - THE STUDENT ORGANIZATION

Symbiosis has the past year organized several social activities and gatherings for the industrial ecology students. The Wednesday night social is a reoccurring event where members can meet and get to know the other students outside of school. In addition, there are several parties throughout the year such as the Halloween party and the Bollywood party.

Many of the events Symbiosis arranges introduce the international students to traditional Norwegian way of living. The "Buddy Week" arranged in the beginning of the school year is organized so that the new students get to know NTNU, Trondheim, the Norwegian culture and the other IndEcolers. At the yearly cabin trips students experiences how it is to live without water and electricity and see untouched Norwegian nature. The Christmas workshop gives members a chance to learn how to make Norwegian Christmas decorations and taste the traditional food and drinks of this season.



Also this year, Symbiosis successfully arranged "Miljødagen" an environmental career day with visiting companies relevant in the field of industrial ecology. "Miljødagen 2010" had over 12 different companies and organizations participating, two of them non-profit. This day contributed with expertise, networking and recruiting. It gave students insights into different sectors that have an environmental and sustainability focus, but it was also a good day for marketing the Industrial Ecology Programme.

In addition to planning social events and "Miljødagen", Symbiosis has tirelessly been improving its web and social media presence. With the redesign of the Symbiosis website, a resource has been created that makes the knowledge of past IndEcol cohorts available to prospective students around the world. Similarly, the creation of Symbiosis "Event Blog" has helped raise awareness of the social events that are held;

thereby increasing student turnout. By using the blog in conjunction with Symbiosis' Facebook page, the information flow to program students has drastically been improved. Finally, the creation of a Facebook Fan page for our newest reoccurring event, Symbiosis Talks, has facilitated online interaction between program students on a wide range of topics.

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Masterstudents celebrating 17 May - The Norwegian National Day

INTERVIEWS WITH MASTER'S PROGRAMME STUDENTS

Oddbjørn Dahlstrøm

Second year master's student Oddbjørn Dahlstrøm grew up in the city Larvik, located in the southern part of Norway. For him Trondheim has always been "the place to go" after high school, and since his brother and many of his friends were there, the choice was easy.

In 2004 he started his bachelor degree in Logistics Engineering at Sør-Trøndelag University College. After his bachelor he wasn't quite sure what he wanted to do further, so he moved back home and worked at "Findus" – making fish au gratin and fish fingers for six months, saving up money so he could travel in Asia. In

Asia he felt that people threw litter all over and didn't think about the environment. On a ferry trip he saw that people gathered litter in plastic bags, and thought "finally, someone who is doing something good" – just to discover that they threw the bags overboard.

After spending a year of thinking on what to do next, he felt that he wasn't finished with Trondheim, and knew that he wanted to take a master degree. Searching the internet, it was a coincidence that he came across the Industrial Ecology Program. With an interest in the environment, he felt that this program was a good match with his background in Logistic, where he had studied the flow of goods around the world.

Oddbjørn is currently writing a project thesis on how to calculate life-cycle impacts of making modern highly-efficient windows. LCA is one of Oddbjørn's favorite subjects in the program. He finds the use of matrixes and math in environmental analysis very exciting, mostly because one can see more specifically what part of an industry or a factory that is responsible for the highest emissions. Another thing

he have learned from the program is to have a more overall picture, to not only study a single product or a company, but follow the whole process, from raw material to waste management.

Another useful experience has been the chance to cooperate and discuss in English with international students, most of them from different disciplines. "One does not only look at things from one side, like one usually does on the Civil engineering line – where everyone is kind of raised the same way – but here you have people from all over the world, and some with non-technological backgrounds as well – this is very exciting".

Oddbjørn mentions the Symbiosis, IndEcol's own association for students, as an important contributor to the close and social study environment at IndEcol. Trondheim overall has a reputation for being a great city for students, and Oddbjørn confirms this. He has for the two past years been active at Samfundet – Trondheim's biggest arena for student activity, and with the international student festival in Trondheim, Isfit, which is the world's largest student festival with a thematic focus.

Tobin Rist

Second year master's student Tobin Rist grew up in Caledon, a small town just outside Toronto, Canada. After finishing his bachelor degree in business finance at the Georgia Institute of Technology in Atlanta, US, he ended up working with some fair trade organizations. Fair trade brought him to Thailand, where he decided to transition more into sustainability. Living in a small town, and not in a "foreign bubble" like some did in Bangkok, Tobin

was forced to learn a little bit of Thai since he mostly worked with Thai people. Even though he couldn't imagine living in Thailand permanently, he loved his time there, eating amazing food and driving around on a small motorbike in the streets with the crazy Thai drivers.

Returning to the US he ended up working for a group called South Face, a green building organization, for one year. Knowing that he wanted to do industrial ecology, he used that year to search for different research programs. Starting his search in North America he didn't find anything he liked, and went on to the European ones, and finally ended up at NTNU.

He likes the IndEcol program because of the freedom to choose your track and the opportunity to reach out to different faculties without any prob-

lems. He thinks that in North America things are a little more rigid, and you have to fit in to what is already there.

Tobin is currently working with the LCA of buildings, especially focusing on the use of building information modeling (BIM). He uses computer modeling and other tools to create a virtual model of a building that can act as a source of data for a LCA before the building is actually built. In future work he feels that he will have great use of the analytical tools that he has learned. Coming from a financial background he has had a few challenges in subjects like energy and environmental consequences, but it also forced him to learn some stuff that he hadn't taken in school before.

Asked of what to do after he finishes, he has no clear answer. One option is to continue his work at NTNU

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INTERVIEWS WITH MASTER'S PROGRAMME STUDENTS

as a PhD student, and another option is to enter the industry as an environmental analyst within construction consulting. He also finds working within big organizations like SINTEF and Byggforsk interesting since they have started to do LCA on buildings.

It doesn't seem like Tobin has any plans of leaving Trondheim in the near future, despite the cold winters. "I like learning about different cultures in general, but getting to know Norway and Scandinavia has been fun". He describes Trondheim as a nice little town, and very "walkable"

and commuter friendly, and recommends a bicycle as a good way to get around. There are a lot of social activities to do at NTNU, and after being active on the NTNU volleyball team, Tobin has now switched to the lacrosse team.

Hilde Kristine Iglebæk



Second year master's student Hilde K. Iglebæk has just returned from a half year stay at the Norwegian embassy in the capital city of Slovenia,

Ljubljana. Here she got a taste of the working life, and admits that she liked it: "It was a very beautiful city and country, and a good feeling to end work at 4 pm - and don't have the student "anxiety" feeling all the time". At the embassy she did a variety of tasks, like preparing reports, arrange different events and keep the webpage up to date. She did not have a special focus on environmental issues in her work, but she got some insight into Slovenia's environmental

policies. The general impression was that environmental policies were developing, but during her stay Slovene politics were overshadowed by financial worries.

Hilde has a background in European Studies from NTNU. She ended up at IndEcol at a coincidence, hearing about the program through a friend and wanted to check it out. With an interest in EU policies, especially in regards to the environment, she found that the IndEcol program was very interesting and relevant. It was however quite a challenge to come from a non-technological background and start doing LCA and Matlab. Hilde took the challenge, and discovered that she found it exciting to learn technical subjects, and that she worked well in groups that had many different academic backgrounds.

Hilde is now writing her master thesis on "The Norwegian Government Pension Fund Global (GPF) and the exclusion principles", where the purpose is to evaluate the exclusion principles and

suggest improvements especially connected to sustainable development and environmental performance. She is also exploring which environmental criteria are used for excluding companies on an environmental basis. Asked of what she wants to work with after she finishes, Hilde mentions several possibilities, but mainly she wants a job dealing with environmental politics and/or management. The thing Hilde likes the most about Trondheim is its volunteering community; "You never have to get bored here if you don't want to, because you get volunteer duties thrown after you, and I don't think this exists in any other city". Hilde herself has been active with NTNU Handball, and has for several years been, and still is, active within ISFiT. On her free time Hilde likes to go hiking, skiing and socialize with the other students through Symbiosis events. She thinks Symbiosis is a great initiative, and hope that future students will keep developing and enjoy it.

Karoline Petersen



First year master's student Karoline Petersen was born and raised in Oslo. She originally started a 5 year long study programme in environmental physics and renewable energy at the Norwegian university of Life Science at Ås. However, after being at NTNU as an exchange student, taking LCA and industrial ecology subject, she decided to take her master degree there instead. "It

was a coincidence that I chose the industrial ecology subjects at NTNU, I hadn't even heard about the term "Industrial ecology", but I found out that this was just perfect for me."

She likes that the programme involves a lot of things into the environmental issue: "It's nice that they don't just focus on renewable energy, but discuss other issues that are equally important." Being a first year student she hasn't decided on what to specialize in yet, but she leans toward Material Flow Analysis: "I think that my background from the University of Life science at Ås will come in handy within the system analysis direction, but I also think that environmental management and politics are really exciting as well, so I don't quite know how to combine that." She thinks the industrial ecology subject is

very good:" In this subject we went through all those thoughts you sort of had about the subject, but hadn't managed to put together, and you saw that your thoughts were important. " She also thinks that the programme benefits from having students from different countries and disciplines, but maybe one downside is that some of the subjects might be simplified a bit. " If you want a study that is more general, that is not just biology, ecology or technology, then this is a great study programme which brings up a variety of aspects."

In the future Karoline wants to work in place where she can do "the most" for the environment, but she does not know what place that would be yet. She enjoys living in Trondheim, and thinks it is a nice city. In her free time she enjoys the outdoors, and also thinks about beginning in a choir.

MASTER'S THESES PRESENTED AT THE AWARD CEREMONY 2010

Elin Staurem	Climate change assessment for socially responsible investments
Line Nes Jordahl	Studiet av prosessen bak utviklingen av en FoU-strategi i Energi21: Hvordan blir en strategi dannet i et nettverk av ulike aktører fra offentlig sektor, næringsliv og utdanning og forskningsinstitusjoner?
Line Rød-Knudsen	Sustainable Smart House Technology Business Models
Ajodeji Ericson Oyewole	Implementation of Land Use and Land Use Change and its Effects on Biodiversity in LCA
Charlotte Roux	The Life-Cycle performance of Energy using household products
Christine Hung	Environmental Impacts of Renewable Energy
Denis Voisin	The connection between city form and daily travels: an empirical analysis in Trondheim
Evangelos Kalogiannidis	Waste to heat LCA, Exploring scenarios for the district heating in Trondheim
Frida Røyne	Multinational Extractive Industries, Environmental Performance and Corporate Responsibility
Guillaume Majeau-Bettez	Evaluation of process and input-output based inventories for environmental assessment of our production and consumption activities
Hugo Johansen	Global Aluminium Cycle
Lars Gunnar Furelid Tellnes	Scenarios for organic (food- and garden/park-related) waste management and energy recovery in the A-ward in Mumbai, India
Ni Made Arya Dhaniati	Historic Patterns of Passenger Car Use and The Future Energy Consumption of The Chinese Car Stock
Pengchao Liu	Dynamic MFA of Indian steel cycle
Rayson Ho	Developing an approach to organic waste management in the city of Rio de Janeiro, Brazil
Suphichaya Suppipat	Designing Bathroom System for Future Scenario
Tilde Nygård	Scenarios for the European aluminium cycle and implications for energy use in production
Tuva Grytli	Integration of methods for environmental assessment and investment analysis
Yan Wei	Dynamics of aluminum in Motor Vehicle of China



Masterstudents and their supervisors after the award Ceremony 2010

PRESENTING THOMAS MARTINSEN: "Technology Learning in a Global-Local Perspective – the Interplay Between Technology Diffusion, Niche Markets and Experience Curves"



Preventing dangerous global climate change requires timely deployment of nascent energy technologies with zero or low CO₂ emissions. The International Energy Agency (IEA) calls for no less than an energy revolution. A key barrier is that the cost of electricity from these technologies is today higher than traditional technologies, e.g., coal power. The high cost, however, is not constant. The technology manufacturing costs, and thus electricity generating cost, will be reduced as accumulated global production increases. This process taking place in a competitive market is called technology learning. The relationship between cost and accumulated production may be represented by a technology learning curve. This thesis discusses technology learning in a global – local perspective. Moreover, it presents new methods to explore the effect of technology learning in energy system analysis of a small open economy like Norway.

In analysis of the global energy system accumulated deployment of the different technologies is often used as proxy for the accumulated production. Deployment will then reduce the cost and from a local perspective be perceived as spillover of technology learning. For a small open economy like Norway spillover may be decisive for the least cost choice of new energy technologies to meet the growing demand for energy. Because spillover depends on the global deployment of each technology, it is scenario dependent. For example, the influence of spillover on the cost of wind power will be very different between a scenario

dominated by nuclear energy and coal power with carbon capture and storage and a scenario dominated by renewable energy. A global model of the energy system is therefore used to estimate spillover. Another important parameter for the development of the national energy system is demand for energy. It is obtained from a macroeconomic model of the national economy. The modelling framework is shown in the figure.

Spillover influencing the development of the energy system will also interact dynamically with the other sectors of the economy, e.g., through change in prices of the energy carriers. The influence of spillover on the non-energy sectors of the Norwegian economy is modest because all existing electricity generating capacity is hydroelectric and thus compatible with the low emission policy scenario. In countries where most of the existing generating capac-

ity is applied for the other technologies while a technology learning curve is specified for OFW. The latter scenario may indicate if OFW may become competitive in the national niche market alone.

The analysis shows that spillover from different global scenarios significantly affects the system cost, CO₂ emissions and technology composition of the energy system of a small open economy like Norway up to 2050. Offshore floating wind power (OFW) shows particular sensitivity to technology learning. The national energy system development only includes OFW when spillover is present or when a high learning rate is assumed in the national niche market. The results indicate substantial benefit for Norway from spillover under the global emission reduction scenarios. Contra-intuitive, global technology learning may reduce both nation-

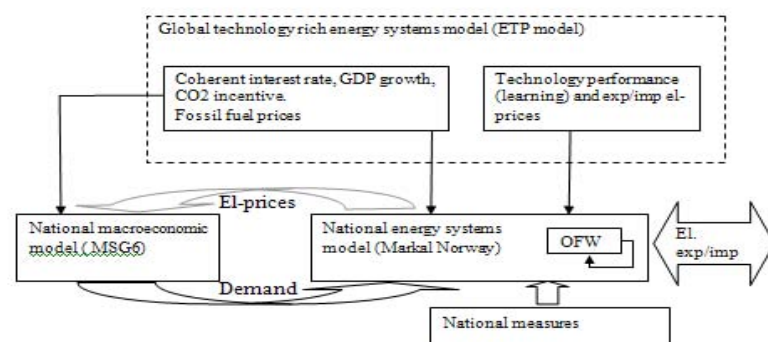


Figure: The model set-up consists of three models where the link with the global model provides a boundary condition for both the national models. The Markal Norway model handles the energy system, while feedback from the non-energy sectors of the Norwegian economy is provided by the macroeconomic model MSG6. The special case, where there is assumed a national niche market for offshore floating wind (OFW) is indicated by the feedback loop within the national model box (Martinsen 2010).

ity must be replaced by nascent energy technologies or power plants with carbon capture and storage the influence on demand is expected to be more significant.

A set of scenarios have been selected to investigate the influence of - and sensitivity to - spillover. In two of the scenarios one selected technology, offshore floating wind (OFW) does not benefit from spillover. That is, the developed framework for

al CO₂ emissions and total system cost. That is, if the industrial and electricity export opportunities, provided by the large offshore wind resources, are exploited.

The dissertation was successfully defended on 14 December 2010.

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PRESENTING VENKATESH GOVINDARAJAN: Systems performance analysis of the water and the wastewater system in Oslo



Introduction: An advanced urban water and wastewater network – from the source of raw water to the sink for the treated effluent wastewater – is, to say the least, a complex one. The interdependencies and interrelationships among the constituent network components make an integrated network analysis as necessary for an as-thorough-as-possible understanding of the system, as a separate analysis of each of the different network components. Utilities should aim at providing acceptable levels of service to the consumers, while optimising the expenditure of money, the consumption of energy, chemicals and materials, and reducing environmental impacts. This is the triple bottom line approach (social-economic-environmental) which needs to be incorporated into asset management of the 21st century.

IE tools and methods: Material flow and stock analysis, energy analysis, environmental life-cycle assessment,

life-cycle costing, and embodied energy analysis are used to study the system performance over time. The elaborateness of the studies, when it comes to historical (time-series in other words) analyses, is limited only by the non-availability of detailed data, and the aversion to make too many assumptions.

Findings and gleanings: As the water and wastewater pipeline networks evolve towards saturation, the annual environmental impacts decrease over time, and are increasingly dominated by the operation, maintenance and rehabilitation phases. Concrete is the dominant pipe-fabrication material in the wastewater pipeline network, while ferrous metals dominate the water pipeline network. LCC enables one to prove the superiority of a physical life-time approach over the in-vogue economic lifetime approach, when it comes to economising and managing/utilising the pipeline assets more efficiently.

The economic and environmental analyses of WTPs and WWTPs in the city give interesting results, when the energy consumption, costs and associated environmental impacts, are compared with the corresponding values for chemicals. Eutrophication emerges as the dominant environmental impact when wastewater treatment and effluent discharge are considered, pointing to the possibility of channelling funds towards nutrient removal in the WWTPs, or looking upstream to initi-

ate source control measures to impede the release of nitrogen and phosphorus into the wastewater. The capture and utilisation of biogas has played a significant role in avoiding the production of natural gas and electricity, and the associated environmental impacts.

Thinking of the urban water and wastewater system as a single entity composed of interrelated components may possibly be easier on paper, but translating the knowledge of the interconnectedness to the adoption of new approaches to the management of the assets, is beset with numerous challenges. In a complex system in which there are 'wheels within wheels', changes or modifications made in one part, may have immediate or delayed effects on the others. Just as the component parts of the system are interconnected, so are the social, economic, environmental and functional aspects of sustainability. The priorities are never the same over time. There are innumerable external factors beyond the control of the utilities which need to be taken into consideration. Sustainable development of urban water and wastewater systems is verily a tight-rope walk. Sustainability studies are *never* completed.

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Launch of new book on Input Output Analysis for Sustainability

In June 2010, a new book entitled "The Sustainability Practitioner's Guide to Input-Output Analysis", was launched at the International Input-Output Association annual conference in Sydney, Australia. Co-edited by IndEcol post-doctoral fellow Richard Wood along with Joy Murray from the Integrated Sustainability Analysis group at the University of Sydney, the book provides a plain-language layman's guide to input-output analysis for sustainability decision making. The book draws from leading academics and sustainability I-O practitioners from around the world in creating an introduction to the use of input-output techniques for probing some of the most crucial questions in Industrial Ecology.

"...this time around success will need to be measured not by how much we can con-

trol nature but by how well we can live as part of it. Our efforts in the transition to a sustainable future require decisions that not only acknowledge the ecosphere, but embrace the complexity of our societies and the natural systems that support us. A vital part of this transition is communication. We need to map and communicate as clearly as possible the impacts of our current trajectory and provide a clear and comprehensive system for tracking the world's progress towards sustainability.

This book provides an introduction to input-output analysis for sustainability practitioners. It is designed for those with knowledge about the sustainability dilemma we face, but who are unsure about the how of measuring our impacts, tracking our progress and in

forming the decisions for a sustainable future. Input-output analysis placed in a transdisciplinary setting is a method that captures the complexities and interdependencies of our social, economic and environmental support systems. Examples of the use of input-output analysis in life-cycle assessment, triple bottom line accounting and carbon and ecological footprints are provided along with an introduction to a range of software tools. In academic circles research has been gathering pace on these methods and issues over the last years. This book brings this state of the art to the decision makers and policy shapers of today."

<http://onsustainability.com/2010/06/18/the-sustainability-practitioner%E2%80%99s-guide-to-input-output-analysis/>

PRESENTING ALUMNUS RAGNHILD BØRKE



Ragnhild graduated from NTNU in 2006. She started to follow the old model of the industrial ecology program when taking her bachelor degree in economics and political science. She continued with a master degree in industrial ecology, writing a thesis on "Energy efficiency in non-residential buildings – Motivation, Barriers and Strategies." On why she chose to study industrial ecology she says: "I had general interest in environmental issues, but did not know much about industrial ecology as such. Before starting I particularly wanted to study environmental politics and economics, but the introductory course opened my eyes for a lot of other issues. So what I have appreciated the most during the study is actually the more quantitative approaches and how descriptive analysis of systems is linked to what can be done at the policy level to make improvements."

Ragnhild is now working as an adviser within waste policy and energy policy at the Ministry of the Environment. This ministry has a particular responsibility for the governments' environmental policy. It includes preparing proposals for new laws and regulations, implementing decisions of the Parliament, cooperate with other ministries on environmental measures in their sectors, negotiate and follow up international agreements and in general being a secretariat for the Minister of the Environment.

Her work includes a daily follow up of any questions about the government's policy and regulations in these areas,

and considering changes in regulations and other policy instruments. "It also includes preparing the political leaders of the ministry in any situations when they deal with "my" policy fields." On how much her background in industrial ecology influenced her career path she says: "First and foremost the industrial ecology study made it obvious to me that I wanted to work with environmental issues some way or another, and it also made me aware of what work options that existed. More specifically, both my current fields of work, waste and energy, are areas that I got to know and became interested in through the study program."

Entering the job marked with a master degree in industrial ecology often requires some explanation "when I describe what my education includes, I usually get positive reactions. However, I think employers (and other professional contacts) prefer to be able to classify employees according to traditional educations. I have sometimes got the question "but what are you really?" (i.e. social scientist, economist etc)." Ragnhild has a positive perception off the job marked for industrial ecologists, and feels that the education is relevant for a lot of different positions, both within government, industry and consulting." I think that the industrial ecology study program focuses more on solving real world problems than does traditional studies (at least in the social sciences), and that this may be an advantage in the job market."

Ragnhild is frequently using industrial ecology knowledge and methods in her work, though mostly as background knowledge: "In my job, I receive a lot of information. Interest organizations, companies etc. wants to influence the positions of the ministry, and there are policy documents that really needs interpretation. I use industrial ecology as part of the background towards which I consider this information and as an approach to analyse effects of different regulations, taxes etc. I also use a lot of factual information from the study, particularly on waste management

and extended producer responsibility." She feels that the knowledge and methods learned in the program correspond fairly well with what is needed in her job." Working in a ministry requires that you "jump into" any issue that comes up, and I think the range of different subjects that is covered in the study program offers a quite good background for that, and a good background for learning more about the issues that you need in-depth knowledge on."

Asked of suggestions to what the IndEcol programme maybe should cover in the future, she mentions: "I have been surprised of how strong the position of classical environmental economics is in government and I think it contributes to maintain end-of-pipe approaches to environmental policy. I sometimes miss being able to present a way of thinking environmental economics that is more in accordance with industrial ecology thinking". *Would you recommend the programme to others?* "Absolutely! Because it offers a holistic approach to environmental issues and is focused on practical problem solving."

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PRESENTING ALUMNUS JØRUND BUEN



Jørund was one of the first students in industrial ecology at NTNU. While a full study programme was established in 1999 and was developed into the MSc programme in 2005, in the three years prior, a one-year pilot course was offered. Jørund was able to include the industrial ecology pilot course (1997-1998) as an elective in his Master's degree in Political Science. His undergraduate degree included courses in Chinese politics, Political Science, and Environment and development as well as History, all of them fields that have played a part in his future career.

"Around 2000, I actually started an industrial ecology consulting company together with a few others at IndEcol," he tells, "but we never really got started. I focused on developing country and renewable energy aspects of industrial ecology during my time at IndEcol. I have kept that focus since, and will keep it in future. In fact, I have just co-founded Differ, a company whose vision is to transform the way people think about renewable energy in developing countries. It's quite interesting today that even then, in the late 1990s, I was frequently ridiculed for my wish to study Chinese energy and environmental politics, as people thought it irrelevant. The basis for that wish was that Industrial Ecology had taught me about the global industrial metabolism, and that I had seen China's emerging role in it."

Today he is also still working on a consultancy basis for Point Carbon, another company he co-founded with a couple of others (one of whom did his MSc thesis on LCA, way back in 1994). "In my work for Point Carbon I have combined business development work with some advisory and in-depth analysis work, and I previously helped build its news and conference services", he explains. Point Carbon is now the world's leading company in its field, offering news, market research, trading analytics, conference and educational services towards the global markets for carbon credits and allowances, as well as advisory services. In mid-2010, Point Carbon was acquired by Thomson Reuters, a leading provider of news and market intelligence to market professionals.

Point Carbon has recruited a large number of former industrial ecology students. Jørund finds that they have entered Point Carbon with a good balance of disciplinary (engineering or political science) skills on the one hand and a respect for other disciplinary contributions to solving practical environmental problems on the other. "Point Carbon's core competencies are in the intersection between several disciplines (economic modeling, market economics, political science, chemistry, etc); hence the ability to work constructively with people with other disciplinary backgrounds has been crucial for our employees. However, we have not been very good at using industrial ecology directly in Point Carbon's analyses, but are slowly moving closer to doing so. I think we are currently witnessing the transformation of industrial ecology tools and approaches from mainly being the realm of researchers to becoming key tools for policy analysis and evaluation as well as for industry and financial benchmarking."

Jørund has experienced a limited demand for industrial ecology-specific skills so far, but says that people with an industrial ecology education would surely stand among the first in line if cross-disciplinary environmen-

tal analysis skills are requested from candidates. "Point Carbon has never requested industrial ecology-specific skills when hiring, but we are still probably among the leading employers of industrial ecology students so far. I think the job market will grow substantially, especially within corporate/financial benchmarking. There will be a need for people who can transform and interpret the results of e.g. LCAs and I/O analyses in such a way that decision makers can make use of them". He thinks corporate and product carbon footprinting will become more and more mainstream, and that footprints will be redefined to cover emissions and social responsibility aspects further down the value chain: "Industrial ecologists can contribute towards improving the quality of the methodologies and their implementation once companies and organizations, literally speaking, stop dipping their toes into carbon footprinting and start doing the real thing". When asked if he would recommend the industrial ecology programme to others, he answers: "The most inspiring (and successful) professionals I have met, including two of my co-founders, have combined core engineering and quantitative analysis skills with environment and development skills as well as social science skills. That combination should be pursued by more students".

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Current positions:

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Co-Founder of Differ

Company/organization:

Point Carbon, Differ

<http://www.pointcarbon.com>

PointCarbon

RIPENSA/IndEcol Symposium “Towards a sustainable society: Exploring the human dimension” – August 2010

In August 2010 the research group for Risk Psychology, Environment and Safety at the psychological institute and the Industrial Ecology program jointly organized a symposium with the environmental psychologist Paul C. Stern as key note lecturer (see box for details on Paul Stern). The interesting symposium received a large audience and was introduced by a welcome address by NTNU's pro-rector for research, Kari Melby. She outlined the importance of interdisciplinary research on climate change and sustainability at NTNU. Afterwards Jonas Enge (Norwegian Research Council) presented the research councils perspective on interdisciplinary research related to climate change.

In his lecture Paul Stern sketched the important role of social and behavioural science in understanding people's reactions to climate change with a special emphasis on his home discipline psychology. He underlined that psychology has a lot to contribute to the pressing problems connected to climate change and sustainable lifestyles and that psychology contributes the most in an interdisciplinary context where the different perspectives complement each other. Areas where psychology can contribute are understanding and changing environmentally significant behaviour, understanding of and responses to environmental threats.

With respect to changing environmentally significant behaviours he pointed out that it is important to identify behaviours with the largest potential positive impact. In his understanding this means not only to take into account the technological and economic potential a change in behaviour might have, but also the psychological willingness and ability of people to change this type of behaviour. He addressed the latter aspect as behavioural plasticity. The environmental impact a behaviour change has is therefore the product of the technical potential a change in behaviour or implementation of new technology might have, the behavioural plasticity and the number of people that could be targeted. The most relevant behaviours are therefore behaviours that many people are willing and able to implement to a large degree and that at the same time have a large technical potential. However, also behaviours with a medium effect that could be implemented by a large number of people could be interesting targets.

Using this combined technological and psychological perspective Paul Stern identified a list of seventeen household actions that could considerably reduce the CO₂ emissions of the US among them investments into fuel efficient vehicles and weatherization of houses as the two investment behaviours with

the largest environmental impact and driving behaviour (fuel efficient driving and reduction of unnecessary car use) and car-pooling as the two most efficient changes in everyday behaviour. According to Paul Stern, a large potential lies in increasing plasticity of behaviours, hence making sure that more of the technical potential is actually tapped. With respect to increasing behavioural plasticity he outlined that intervention strategies have to be well planned and coordinated to tap the full potential. Monetary incentives for example have been shown to have quite differing success rates, depending on the area and way of implementation.

A concluding panel discussion with Paul Stern, Even Bjørnstad (ENOVA), Edgar Hertwich (Industrial Ecology, NTNU), Ellen Matthies (Risk Psychology, Environment and Safety, NTNU), Arnold Tukker (Industrial Ecology, NTNU) and Annemie Wykmans (Department of Architecture, NTNU) took an interdisciplinary perspective on the challenge of climate change and changes towards a sustainable lifestyle.

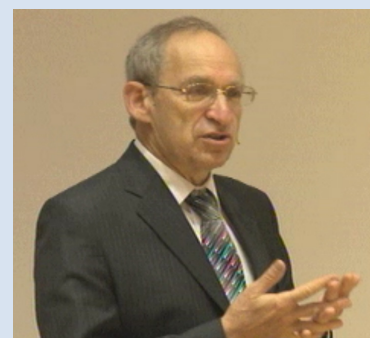
A video stream of Paul C. Stern's lecture can be found here: <http://www.ntnu.no/psykologi/forskning/ripensa>

About Paul C. Stern:

Paul Stern is the Director of the Committee on the Human Dimensions of Global Change of the U.S. National Academies of Science and co-author of the task force report of the American Association of Psychologists on "Psychology and Global Climate Change: Addressing a Multi-faceted Phenomenon and Set of Challenges". He is an outstanding internationally renowned psychologist in the field of global environmental change and sustainable consumption. His research interests include understanding the determinants of environmentally significant behavior by individuals and the struc-

turing of institutional systems through which people can participate in the governance of human-environmental systems. He is author of more than 100 publications, most of them written in interdisciplinary collaboration e.g. with economists and sociologists. He co-authors several publications with current Nobel Prize winner Elinor Ostrom.

The APA task force report can be found here: <http://www.apa.org/science/about/publications/climate-change.aspx>



REVEALING THE ENVIRONMENTAL PROFILE OF BIOENERGY

In 2009 NTNU and the Industrial Ecology Programme became a research partner in the 'Bioenergy Innovation Centre' – CenBio – one of the 'Centres for Environment-friendly Energy Research' (FME) established by the Norwegian Research Council.

2010 has been the first full year of activity. The activities at IndEcol has primarily focused on reviewing present state of knowledge, developing and testing models on the effect of logging on in particular the carbon balance, and performing case studies on the environmental profile of bioenergy production systems.

A performed review shows an increasing number of LCA studies on bioenergy, but a lack of focus on in particular effects from land use and land use changes. There are also huge uncertainties in the studies on e.g. fertilizer induced emissions. Another ongoing review shows that there has also been very little development of methodologies to assess the impact on biodiversity from direct and indirect land use changes.

In most of the existing LCA studies, CO₂ emissions from bioenergy systems are considered climate neutral if the system is carbon neutral. However, before the carbon is captured by vegetation re-growth, the CO₂ stays in the atmosphere for a period of time and contributes to radiative forcing.

A model aiming to assess this effect has been elaborated. This model provides the atmospheric decay function of biogenic CO₂ as a function of the biomass rotation period. This makes it possible to estimate the contribution to climate change when biogenic CO₂ is released to the atmosphere. One of the advantages of this model is its attributional nature which eliminates the need of identifying a fossil reference system in order to be able to quantify the GHG emissions from a bioenergy system.

This approach has important consequences both at a project and national level. At a single project level, it address-

es the need for unit based indicator that can be included in the assessment. At a national level, it offers an opportunity to revise the existing national responsibilities for CO₂ emissions from bioenergy within the Kyoto Protocol.

A land use model of carbon accounting in Norwegian forests ("Norwegian Wood") has also been developed for analyses of future bioenergy scenarios in Norway. The model is exogenously driven by defining scenarios of species-specific annual outtake (volume) and logging residues based on their constituents. Age class and species-specific area (ha), density (m³/ha), and yield (m³/ha/yr) data from Norway's 7th National Forest Inventory are used together with biomass expansion factors to develop the model, which projects total annual fluxes of carbon across five carbon pools over a 100-year management period. The newest version of Yasso forest soil carbon model – Yasso07 – is coupled with the model in order to quantify net carbon fluxes from the soil organic carbon pools.

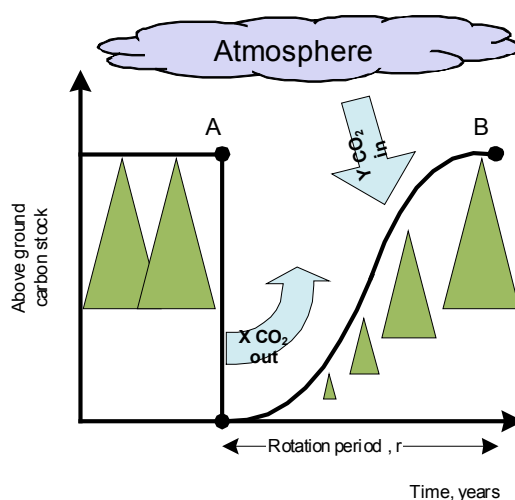
"Norwegian Wood" has been used together with remote sensing data to track albedo changes on harvested areas within Norwegian forests. Preliminary results show that, in an expanded outtake scenario, the climate benefit due to a changing surface albedo more than offsets – by a factor of ~3-4 – the climate impact from lost carbon sinks. This implies that it is highly necessary

to consider biogeophysical effects like albedo in addition to biogeochemical (carbon) considerations before sound policy can be implemented, particularly in high-latitude boreal forests.

One important outcome of the research will be recommendations on best use of biomass for greenhouse gas mitigation. At the moment, this is a topic for future research, but in order to approach the goal, several bioenergy production systems are studied in detail. This includes systems for biofuel production, combined heat and power systems at different scales and biorefinery systems. Work is also initiated to gain a better understanding of the material flows in the entire forestry and forestry based sector in Norway in order to better be able to understand the connection between the production systems and the distribution of environmental impact throughout the entire sector.

A prominent part of the work in 2010 has been networking in order to achieve contacts with relevant research groups throughout the world. A range of conferences is attained, as well as workshops and research networks, such as the IEA bioenergy task 38 on GHG balances of biomass and bioenergy systems and work initiated by the Joint Research Center Ispra on carbon storage in products.

Figure: CO₂ released from combustion of bioenergy might stay in the atmosphere for a period of time and thus contribute to radiative forcing, preventing the systems from being climate neutral. A model for assessing this effect has been constructed and implemented in LCA studies.



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IndEcol@IVM 2010 HIGHLIGHTS

Our active and highly competent students at IVM (Department of Hydraulic and Environmental Engineering) nowadays always use the term **IndEcol@IVM** when referring to our group, so let's do that here as well. At the end of 2010 we are 3 professors, 7 PhD students, 7 MSc students and two research assistants in our group, and as such we are one of the more active nodes in the industrial ecology network at NTNU. Our current focus is to advance the scientific understanding of how to reduce environmental impacts of resource use and waste generation in society. In particular, we apply various modelling approaches in order to analyse the societal metabolism to reduce material and energy use and emissions for urban infrastructure systems and for global material cycles. From our achievements in 2010 we highlight a few ongoing and new research initiatives.

Strengthening industrial ecology in urban built environment research

Contact person: Professor Helge Brattebø

During the last few years our group has systematically tried to better link the systems perspectives and the quantitative environmental analysis methods of industrial ecology to built environment research. Our aim is to develop a more in-depth understanding of the critical sustainability variables and dynamics of built environment (i.e. buildings and infrastructure) and cities (or what you could also call urban systems), because we know that such systems are major consumers of resources and emitters of harmful substances.

In 2008 we hosted an international workshop titled *Analysing Stocks and Flows of the Urban Built Environment*, which gave

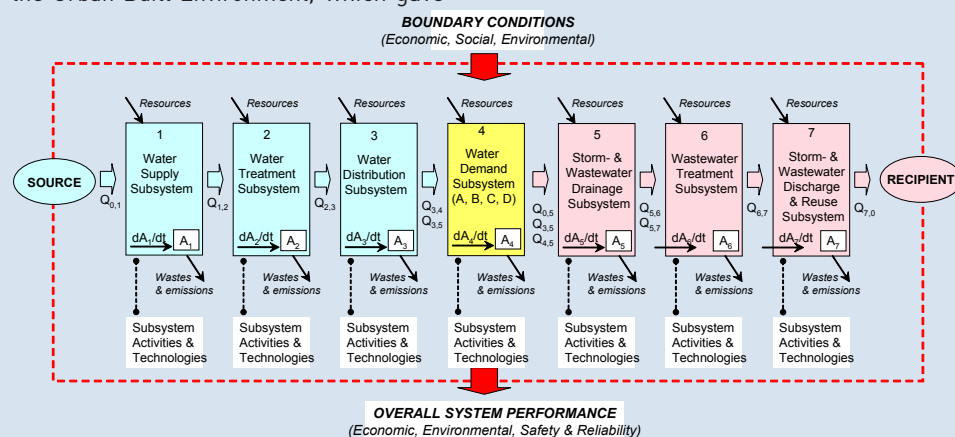
us a good start for international collaboration in the emerging field of Urban Metabolism. One such opportunity is an active participation in the *Sustainable Urban Systems* section of the *International Society for Industrial Ecology*, established this fall. Another opportunity is our collaboration with the Urban Metabolism group at the *MIT-Portugal Programme*, currently developed by Helge Brattebø who is now Visiting Professor at the Instituto Superior Técnico in Lisbon.

This fall IndEcol@IVM participated in two EU7FP research project proposals relevant to urban built environment research. One is titled *CITY-SENSE*, where we plan to collaborate with the Potsdam Institute for Climate Impact Research, TU Berlin and Tecnalia (Spain) on developing further dynamic spatially explicit MFA models for buildings and infrastructure in urban systems. Here we will also collaborate with Architecture departments at NTNU, using Trondheim as a case study city. The second proposal is called *EFFECT-W*, coordinated from Budapest, which is about evaluating the effectiveness of solid waste management policies in selected European countries. Furthermore, we are preparing for our active participation in the EU7FP project *TRUST* (TRansitions to the Urban water Services of Tomorrow), which got successful funding this year and will run from January 2011 through 2014. Industrial ecology thinking, using a metabolism model (cfr. the figure below) combined with systems dynamics modelling, is actually one of the core approaches to explore sustainability aspects of European urban water infrastructure in this project, using Oslo as a model city.

In 2010 IndEcol@IVM successfully contracted the 3rd phase of the research project titled ETSI (Bridge Life Cycle Optimisation), funded by the national road authorities in the four Scandinavian countries, and including also groups at KTH and Aalto University, as well as COWI in Denmark. Our role here is to finish the development of our unique BridgeLCA tool for environmental analysis of road bridges. This year we also successfully completed a project for Trondheim Energy District Heating analysing accumulated CO₂ benefits (and NO_x disadvantages!) of waste to energy substituting fuel oil for heating of buildings in the city from 1986 to 2008.

Material Flow Analysis (MFA) has become an important method for the metals industries to inform strategic decisions related to resource efficiency and recycling. The aluminium industry has been particularly pro-active in this, among others because recycling drastically reduces energy demand and improves the environmental profile. Norsk Hydro has played a vital role in these efforts: In cooperation with Alcoa, the European Aluminium Association, and the International Aluminium Institute, they developed a first model of the global aluminium cycle. In 2009, they sponsored a PhD student at IndEcol@IVM to further develop this model and extend its scope. This has resulted in a close cooperation with Hydro with synergies for an existing aluminium project, several Masters theses, and additional research funding (post-doc starting in 2011).

From 30 September to 1 October, 2010, we organized, in collaboration with Norsk Hydro, an international workshop on The Roles of Metals in Climate Change Mitigation, in Ålesund. The aim was to explore ways how the metals industries and their customers (mainly automotive industry) can contribute to overall reductions in greenhouse gas emissions, either within their own businesses or through cooperation with other industries, and how industry strategies could be informed most effectively by analytical tools such as material flow analysis or lifecycle analysis. The workshop was attended by 31 participants, including a handful of students, from the metals industry (Hydro, Alcoa, Inter-



national Aluminium Institute, Organization of European Aluminium Refiners and Remelters, Novelis, Eurometaux, Nickel Institute, Arcelor Mittal, Mefos, WorldAutoSteel], the automotive industry (Audi, Jaguar Land Rover, Renault), and universities (NTNU, Cambridge University, Yale University, Tsinghua University, KTH, Forschungszentrum Karlsruhe). After the workshop, Hydro invited all participants for a boat tour to the Hjørund fjord, where we visited the famous Hotel Union Øye, an unforgettable experience.

As a spin-off of our research collaboration with Norsk Hydro, we were invited to join a consortium applying for another EU7FP project; GRACE (GReen Aluminium Car Evolution), which is a large-scale integrating project (total budget 15 million Euro) under the programme topic The Eco Factory: cleaner and more resource-efficient production in manufacturing. The motivation of the project is to develop new technologies to reduce overall greenhouse gas emissions by making vehicles lighter (e.g., substitute steel for aluminium) and by producing aluminium from secondary resources of end-of-life vehicles, which saves about 95% of the energy compared to primary production. Coordinated by Daimler AG, the project includes participants from 20 institutions (automotive, OEM's, aluminium) and universities. NTNU's role will be to evaluate different strategies for aluminium employment in vehicles and recycling in terms of the long-term impacts on the overall aluminium cycle (e.g., change in aluminium demand or scrap availability) and on overall greenhouse gas emissions (direct and indirect emissions) by use of a dynamic material flow model.

NTNU is now chairing the ISIE MFA-ConAccount section

Contact person: Professor Daniel Müller

Over the past two years, the International Society for Industrial Ecology (ISIE) has launched a number of topical sections to advance the development of industrial ecology methods or to identify combinations of methods to solve specific problems. One of these sections is called Material Flow Analysis – ConAccount. The MFA-ConAccount section was formed from a previous network of European MFA researchers called ConAccount, which organized conferences since 1998. This transition allowed the ConAccount network to become a more formal institution with a global orientation. In 2008, the ISIE Board formally approved the new section and its by-laws, and in 2009, the first elections were held. Daniel Müller from NTNU and Helga Weisz from the Potsdam Institute for Climate Impact Research (PIK) organized the transition from the ConAccount network to the ISIE section, and Daniel Müller was elected as the first Section Chair.

From 7-9 November 2010, the Japanese National Institute for Environmental Studies (NIES) organized the first ISIE MFA-ConAccount section conference in Tokyo, back-to-back with the ISIE Asia Pacific chapter conference. About 100 participants attended the conference. There was a clear trend towards analytical depth and topical width: from purely descriptive studies towards analytical tools and dynamic modelling, from analyzing individual materials towards exploring the linkages between materials, energy, and emissions, from focusing on flows to discovering the roles of stocks, and from focusing on spe-

cific scales towards analyzing multiple scales. An increasing number of presentations addressed the challenges of climate change mitigation and adaptation.

Given this development in MFA research, the main tasks for the MFA-ConAccount section for the coming year will be to define its core, to establish a solid membership outside of Europe, and to strengthen the links to industry and government organizations. In 2011, the section will launch a new website, which will help us in achieving these goals. In addition, the website aims at providing a forum for providers and users of MFA research.

2PC – Two tons per capita

Contact person: Adjunct Professor Kjell Øren

The reduction of the global greenhouse gas emissions to a sustainable level of two tonnes of CO₂-e per capita and year ("2PC") will have major societal implications. Within sectors as energy, industry, transport and buildings, key measures and pathways refer to energy efficiency improvements, renewable energy, carbon capture and storage, recycling of materials, new transport technologies, more and better public transportation and better infrastructure. Production and consumption patterns have to be changed as well.

However, it is less specified how such a future society will look like and function. Which transformations are needed, what are the roles of consumers, governments and business, and what are the implications for the resource cycles? How can a Norwegian 2PC society function in 2050, and how do we get there? In 2010, we held a workshop to search for opportunities to develop such a true multidisciplinary project, combining the unique skills of several departments at NTNU. Taking the complexity into account, adding elements to ongoing activities turn out to be the preferred pragmatic option for narrowing the scope and simplifying initial actions. To further accelerate the work, it will be necessary to join forces with scientific communities outside NTNU.



Participants of the workshop in sunny Ålesund

The Building and Material Technology research group

The AEC-industry is in the middle of a silent revolution. The way we construct our buildings and infrastructure has to fight a battle on two fronts, on adapting to already ongoing climate change, and to minimize impact on climate change. This applies to both new and existing buildings and infrastructure.

The Building and Material Technology Research group find ourselves in the middle of all this activities, and are together with partners at NTNU and elsewhere involved in a number of research projects targeting this issues. These activities spans from collaborations with architects, planners and social scientist on how to design and build neighborhoods, to research on how to design and build buildings with as little environmental impact as possible. To do so, we need a better understanding of heat and moisture transport in buildings, and what materials and construction techniques to use in doing so. We also need better and more robust materials in the insulation of buildings and in the building envelope.

Another important research question for us, what do we do with all the existing buildings? Since over 80% of

them will still be in use in 2050 and beyond, we need also them to perform a lot better than today in order to move towards sustainability.

To find answers to these questions, we have engaged ourselves in several research projects together with partners at NTNU and elsewhere, of whom we would like to emphasize the following few here:

The Brøset project. What enables people to live with less than 3 tons CO₂ per capita? This involves much more than building performance. In this novel research project we work together with architects, social scientists and planners, as well as the municipality of Trondheim in order to facilitate the development of a new neighborhood with 1200-2700 dwellings in Trondheim, so that the inhabitants can live a "carbon neutral" life. This of course involves more than just buildings, also all transport, energy supply, infrastructure and consumption.

Zero Emission Buildings (ZEB). ZEB is one of the largest research projects in the AEC industry in Norway for decades. This 8 year and 300 mill. NOK project hosted by NTNU and SINTEF, involves over 20

partners, and aims at finding solutions, techniques and the materials needed to construct the future buildings with net Zero Emissions. ZEB also investigates what to do with existing buildings, although its main focus is on new buildings.

FramTre (KlimaTre). This project is the first project in Norway that covers the complete value chain of wood and products made from wood. The aim is to understand the dependencies and co-products within the system and the environmental impacts from their production. We are involved with the LCA studies in this project, with a special focus on the construction materials.

RoBust. How to construct building envelopes that is robust and environmental friendly? What techniques and materials to be used? We are involved in this SINTEF research project seeking new and robust solutions to new building envelopes with an increased thermal performance, which demands new solutions to air tightness and moisture transport.

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Department of Industrial Economics and Technology Management

The Department of Industrial Economics and Technology Management was very active in 2010. This year the project in Bhutan on Cleaner Technology and Environmental Management was concluded with a final trip in March. While there, Professor Annik Magerholm Fet, and researchers Uno Abrahamson and Dr. Cecilia Haskins conducted training sessions, and participated in a seminar to raise awareness on this theme with government and business leaders. Additional details are available at www.iot.ntnu.no/csr.

The project Innovation in Global Maritime Production – 2020 (IGLO-MP 2020) continues until 2012. Research contri-

butions were made this year by Børge Andreas Johansen, Dina Aspen and Mieko Igarashi who published working papers on LCA, CSR and water footprints for the shipping industry. Students in Experts-in-Teams also did research on environmental and social implications of current practices in the end-of-life treatment for ships. More information about this project can be found at the project website: www.iglo-mp2020.no.

Students in TIØ4195, Environmental Management and CSR, conducted semester projects with 10 companies and produced poster papers that were displayed during the National CSR Conference in December. Conference partici-

pants were generally very impressed by the maturity of the posters as well as their effectiveness in explaining important issues in this area. The conference attracted 125 people from business, government, and research and educational institutions from all of Norway. Those interested in viewing the plenary talks can find them on www.csr-norway.no.

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The Department of Product Design (IPD)

At the Department of Product Design (IPD), 2010 was an eventful year for activities related to Sustainable Product Design. Early in the year, two PhD students joined our group. Johannes Zachrisson, an interaction designer, with a background from both our own department (B.Sc.) and TU Delft (M.Sc.) decided after some years as a consultant at Tieto, to come back to his alma mater and take up PhD studies in aspiration of a more theoretical background in how user-centred and interaction design can contribute to designing products that facilitate sustainable behavior. In addition, Kirsi Laitala, employed at SIFO (Norway's National Institute for Consumer Research) joined us as a PhD student; she is funded through a National Research Council project on Sustainable Clothing Design. Also she is interested in studying consumer behavior in terms of purchasing, washing and drying, and discarding of, in her case, clothes. Last but not least, we could welcome Dr. Arnold Tukker, a well-known specialist with a broad expertise ranging from sustainable consumption and innovation to environmental modeling and assessment. Continuing at his employer, the Dutch research organization TNO, he joined the Department of Product Design and the Industrial Ecology Programme as a Professor II in a 20% position. Arnold's job will be to deploy his expertise and experience in streamlining joint research projects, contribute with research funding applications, and providing co-supervision to PhD students.

During the spring semester and including the summer, a NFR Yggdrasil stipend made it possible that Elli Verhulst could join us as a guest researcher from the Artesis University College in Antwerp, Belgium. She is in her final year as a PhD student on human factors in the adoption of sustainable design criteria in industry, and this stay allowed for close cooperation with her co-supervisor, Prof. Casper Boks during the final stages of her data analyses.

In the course of the year, we were able to mark our activities by being present at several events. Several papers were pre-

sented at conference such as the CIRP conference on Industrial Product Service Systems in Linköping, NordDesign in Göteborg, the LeNS Network conference on Sustainable Design in Bangalore, and the official conference of the IFIP Working Group 5.7 on Advances in Production Management Systems in Cernobbio, Italy. At the ERSCP-EMSU conference in Delft, we were present with no less than 5 presentations related to Design for Sustainable Behaviour, marking our focus on this theme, which is picking up fast in the Sustainable Product Design domain. A workshop organized at this conference was an excellent opportunity for researchers addressing this theme – of which many were present – to exchange their ideas and make plans for future collaboration.

In September, the Department of Product Design itself organized the 12th International Conference on Engineering and Product Design Education. The conference theme was "When Design Education and Design Research meet...". At this conference, the stream on Sustainable Product Design was the largest of 12 themes, reflecting the interest of the academic design community to study how sustainable design research and education can be organized synergistically. The conference, which was marked as one of NTNU's jubilee conferences, was a great success!

Another activity worth mentioning was the study trip with IPDs 3rd year students to Uganda and Botswana, which had a clear sustainability flavor to it. At the University of Botswana, we worked for a week with 20 local students on two projects, focusing on improving the local bus station, and developing sustainable packaging solutions for a local company involved in social entrepreneurship.

The addition of our new colleagues, and the activities that we were able to employ in 2010, which includes the start-up of several research activities with (international) industrial partners such as Philips, LG Electronics and Glen Dimplex, implies that our research group, further consisting of PhD student Ida Nilstad Pettersen,

postdoc Anne Sigrid Nordby and Associate Professor (20%) Kristin Støren Wigum is now beyond the stage of infancy; in the years to come we promise to establish ourselves further as an internationally leading research group in our field.

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UN RESOURCE PANEL HIGHLIGHTS FOOD AND FOSSIL FUEL AS GLOBAL PROBLEMS - By Edgar Hertwich

It was my big day in Brussels on the 2nd of June: The deputy director of the United Nations Environment Programme, Angela Kropfer, and the EU's Commissioner for the Environment, Janez Potocnik, were there for the launch of our report, *The Environmental Impact of Production and Consumption: Priority Products and Materials*. The report was written by a working group of the Resource Panel under my leadership and published by UNEP. The evening before we spent on our mobile phones, giving interviews to Reuters, the Guardian and other news outlets.

The story, as we framed it, was of a top-down assessment to identify the most important causes of environmental problems - the most important consumption categories, materials and industry sectors. Our assessment clearly pointed to the importance of food production and fossil fuels. Agriculture, pastures and fishing emerged in many assessments as important - to a degree that surprised me. The problem with fishing is that we do too much of it, in too many locations: we are destroying the base of this renewable resource. There are more problematic issues, however, associated with agriculture: it is the dominant cause of land use and hence the change of habitats for animals and plants, threatening biodiversity. It contributes 70% our water use - and water is getting scarce in many regions. In Europe, food production

contributes 60% to the overfertilization with nitrogen and phosphorus - another important cause of biodiversity loss according to the Millennium Ecosystem Assessment. Furthermore, food production causes 20-30% of GHG emissions.

The work by Ester van der Voet, one of my co-authors, on the environmental impacts of material flows in Europe clearly identified meat and dairy products as the main culprits. "UN urges global move to meat and dairy-free diet" was the title in the Guardian - somewhat in contradiction to what I tried to communicate in my interviews. It was, of course, not an incorrect conclusion to draw from our findings, but it was not our mission to produce recommendations. Rather, we wanted to put facts on the table.

What I thought as the really novel contribution of our report in the context of international scientific assessments was not the food story - it was the consumption perspective. It provides novel insights - into what activities, consumption categories and products cause environmental impacts. Our review confirms the triad of shelter, food and transportation as important consumption categories, with the caveats that transportation matters little in poor countries and manufactured products overtake food in some rich countries - as readers of our "Carbon Footprint of Nations" study or website

will know. Our report highlights clearly that our causation of environmental impacts is a strong function of our income - more consumption implies more impact.

Looking at products and consumption clusters, one also finds that much of what we consume is produced abroad. In fact, for some products, the concept of location of production makes little sense - we see increasingly complex products with value chains spanning the entire globe.

I was pleased to see that at several news stories picked up this aspect. In our report, we took a life-cycle perspective. We looked at many aspects and many impacts. Inevitably, there are trade-offs to make. The picture was complex - reflecting a complex reality. Those who bothered to look at the detail will still recognize a consistent picture in which a web of causal relations and interconnections becomes quite apparent - including those aspects we should focus on. The BBC's Richard Black captured this wonderfully: "Sustainability: Choices, choices, choices." It is those we need to understand. And to make.

Please see the [IndEcol website](#) for links to the new stories. Since its launch, the report has been downloaded over 500'000 times and it was the most downloaded document on the UNEP web server in June.

Daniel Müller and Edgar Hertwich selected as IPCC lead authors

The Intergovernmental Panel on Climate Change has selected IndEcol Professors Daniel Müller and Edgar Hertwich as co-authors of the next, 5th assessment report (AR5) on the state of climate science. Both will work in working group III, which addresses the mitigation of climate change, i.e. the reduction of emissions of greenhouse gases.

Daniel Müller is an expert in material flow analysis with a background in planning. His research aims at identifying and evaluating strategies to improve people's quality of life (e.g., by satisfying human needs for food, hygiene, housing, or mobility through built environment stocks) while making the societal metabolism more sustainable (e.g., reducing dependency on critical resources and harmful emissions). He will contribute to the AR5 chapter on Human Settlements, Infra-

structures and Spatial Planning. The growing cities particularly in developing countries are the main reason for the global rise in material and energy demand and greenhouse gas emissions. Developing countries have an opportunity to learn from the mistakes of industrialized countries and build their cities more efficiently from the beginning, while the main task of industrialized countries lies in transforming existing built environment systems. In both cases, strategies for reducing greenhouse gas emissions need to be informed by models and scenarios that adequately capture the links between built environment stocks, materials, energy, and emissions, in order to avoid problem shifts. These links have not been covered in previous IPCC work.

Edgar Hertwich is an expert in life-cycle assessment with a background in en-

ergy & resources who has expanded his horizon to modeling the environmental impacts of consumption and international trade. He will contribute to the chapter on energy systems by looking especially at the environmental and resource implications of low-carbon energy technologies. "Energy conversion causes many environmental problems, but it is also at the heart of our wealth generation. How we change the production and use of energy will have a big influence on the environment and on our economy," says Hertwich. "The work of the IPCC has so far looked mainly at the direct emissions of greenhouse gases. We need to develop solutions that are sustainable in several dimensions, and the research that we are doing in the life-cycle field is indispensable for this."

HIGH PROFIL HIRE - MEET PROFESSOR II ARNOLD TUKKER



Arnold in action as opponent as NTNU professor during a PhD defence in the Netherlands - in the clothing Dutch universities require for professors on such occasions".

Professor Arnold Tukker has since 1st of April 2010 had a 20% assignment as professor II of Sustainable Innovation at the Industrial Ecology Program/ Department of Product design at NTNU. When not travelling to Trondheim, Arnold is at TNO, Delft, Netherlands, dividing his time in his role as Business line manager Societal Innovation and Economy and leading major EU projects for TNO. Examples are EXI-OPOL and its follow up CREEA, in which Indecol researchers like Richard Wood, Jan Weinzettel and Edgar Hertwich are involved too.

Arnold has had a very interesting career so far. He first started out studying chemistry, which he quickly regretted "my student period was not my best time - I think the insight in chemistry was a good foundation for me, but the study itself was not very nice. So I was lucky I graduated." With a combination of chemistry and economic studies he finally graduated, and from then on he felt that luck was on his side. His first job was with the Dutch Environment Ministry in 1988, and he found it very interesting to work with policies because "you really see what you can do to make a better environment." Environment issues were popular and important at that time, in the Netherlands there had for example been a big study that showed how things could go wrong, and one had just had the Brundtland commission.

Then TNO came along and asked if he wanted to work with them, a company that is quite similar to what SINTEF is in Norway. "After spending 2-3 years at the Ministry I was a bit bored, it was just talk and limited action, so I decided to take the job." From then on he started to do much the same work as Edgar Hertwich has been doing, like LCA and waste management studies, and a

lot of work on material flow analysis. "I started doing policy research on really controversial issues. I was relatively young at the time, 32-33, and there were quite some uneasy moments. I was doing waste management plans for the Netherlands, and I and my team had to make scenarios on how much waste was around. I remember we calculated that one of the biggest waste management firms in the country should not expand, because if they expanded they wouldn't find enough waste to bring to the incinerator. The director of the company was of course furious with me."

Jumping a bit forward in time, now at the age of 35, Arnold was kind of famous for his studies on toxicity problems with regard to chlorine and PVC, and he got invitations all over to talk about his work. "One time I was invited to the parliament in one of the German states, and of 20-30 experts sitting there, I was the only non-German expert invited to give an expert opinion on chlorine. Most of them were well-known scientists with great titles like professor or doctor, and when it was time for my presentation the chair said "I think we have a mister Tukker now." German is very formal, so you can imagine they did not take me too serious because I didn't have a title."

Wanting to do something about this, he called his former boss, who at the moment was a professor at Tilburg University, and asked if she thought it was reasonable for him to take a PhD next to his job in TNO. "She said I should go for it. So then I rushed through a PhD in about 2 years next to doing my normal job, which was kind of crazy, but I did it." So in November 1998 Arnold defended his PhD thesis which consisted of a mix of LCA and material flow research on chlorine, and a historical evaluation of the controversy in the Netherlands and Sweden using concepts from the fields of philosophy of sciences, risk perception, and policy sciences.

After this Arnold started to publish quite a lot, and got a name internationally because of his work. After some time he started thinking about getting a professorship somewhere "I started to probe here and there, and there came along a few opportunities, but either I did not want it or it did not work out, but then NTNU came along and here I am."

So why choose NTNU? Arnold had met Casper Boks from the Department of Product Design in a conference in June 2009, and Casper explained that he had talked to the Dean who was in favour of strengthening IndEcol - so Casper suggested that if Arnold wanted to be a professor he should come to Trondheim "Trondheim? Isn't that a smallish town somewhere in the north of Norway? Where it is always dark and

winter? So I was a bit like: yeah... if it was Barcelona or New York, no problem, but emigrating to Trondheim? So then we discussed if there was not an option to do it part time, which indeed also appeared possible." Then in October 2009 Arnold was invited to come to Trondheim, presumably to do a guest lecture, but of course the real mission was to discuss the potential professorship with the Dean, Casper, Edgar, and some other IndEcol staff.

Arnold now thinks he has the best of both worlds; at NTNU he works with groups that are primarily interested in scientific research, and at TNO it is more client based research "I like to work with clients because you see the results are used, and I also like to come to Trondheim, because the group here is very good, one of the top groups I would say globally in industrial ecology." On what he thinks of the future of IndEcol, he is positive and thinks the master and PhD program is quite organized, and everyone is contributing to make it a good, integrated program. Arnold thinks that Indecol still could strengthen itself by improving its common research strategy; "Edgar is working on this, Casper on that, and RIPENSA on another thing, and maybe I am naive, but I think that if you are capable of developing a joint research program, or developing something like a joint concept - what means Industrial ecology for my group?-, and if you can organize it so that it would become clear for the different groups how one can work together, we really can become the global top."

The cold is what Arnold dislikes most about Trondheim, but he thinks the countryside is amazing. He also finds it amazing that people go home early from work "Here I got locked in the building at 4 O'clock, this would never happen in the Netherlands! But I read at a NTNU webpage that Norwegians value the quality of life, and want to spend time with family and friends, and I now see that it's true."

On a finishing note Arnold express that the people doing their master and PhD here at IndEcol should be very happy "they should be happy for two reasons, first because it is a really good program with very qualified and very nice persons as teachers and professors, and second because it is all for free, unlike the UK where you have to pay big money to do a master or PhD."

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