

# Pro-environmental Product Planning in a Dynamic Operational Environment Now and in Future - Methods and Tools (ProDOE)

Report Year 2008

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## 1 The Research consortium members

### **At Helsinki University of Technology (TKK)**

The Institute of Law: LL.D Ari Ekroos, M.Sc. Mari Pajunen, D.Sc. Matias Warsta, M.Law Jaakko Kanerva

The Laboratory of Environmental Protection: PhD Janne Hukkinen (University of Helsinki, August 2008), D.Sc. Olli Salmi

TKK Laboratory of Environmental Technology : D.Sc. Olli Dahl, M.Sc. Gary Watkins, Lic.Tech. Helena Mälkki

TKK Laboratory of Energy Engineering and Environmental Protection: Lic.tech. Carl-Johan Fogelholm, D.Sc.

Sebastian Teir, Lic.Tech. Sanni Eloneva

TKK Laboratory of Mechanical Process Technology and Recycling: D.Sc. Kari Heiskanen M.Sc. Maaria Kinnunen

### **At the Oulu University (OY)**

The Laboratory of Process metallurgy at the Department of The Department of Process and Environmental Engineering:

D.Sc. Jouko Härkki, PhD Jyrki Heino, M.Sc. Esa Virtanen (Manager of CIRU 1.1.–30.4.2008), Mikko Angerman

(Executive Manager of CIRU 1.5.–31.12.2008), University teacher Eetu Heikkinen

## 2 Objectives and Hypotheses

The group will research the complex interactions between the setting of regulatory objectives and the choice of scale of the engineered industrial ecosystems to be regulated and managed as well as the complex interconnections, dynamics and relevant cycle specific boundary conditions. This will require research on eco-efficiency indicators to understand their variability and how the policies chosen interact with these variations. It will also need research on the physical and chemical possibilities for utilization of different streams in the ecological web.

### **Our research hypotheses are:**

- (1) The closure (including optimisation) of resource cycles can only be achieved if all the chemical, physical, technical, economic, legal, administrative, environmental, and social issues are considered together in a systemic way.
- (2) The policy must be discussed from the perspective of all actors.
- (3) We need to understand the implication of the metrics and procedures used.

### **The general objectives of the project are:**

- (1) To produce a position paper of the research group of the existing situation concerning the metal and fibre cycles and the interconnected energy cycle. We will assess the current policies, their spatial and temporal effectiveness and outline existing boundary conditions.
- (2) To identify legislative and regulatory development needs in order to promote sustainable use of resources and the closure of material cycles. We will try to propose some effective policies and legal instruments related to material cycles (legal, technical and economic means to control the material flow).
- (3) To provide new insights into the metrics of industrial ecology by developing further the deterministic indicators so as to better understand the temporal and spatial scales of ecological efficiency.
- (4) To intensify the utilisation rate of side-streams or rejects in the three industrial ecosystems, while taking into account the aspects arising from legislation, management, economy, ecology, material properties and processing. The possibilities for cross-linking the cycles will also be explored.
- (5) To develop a first generation systemic model (generically a model framework) for the chosen material cycles in terms of system interconnectedness and dynamics and use the developed model in conjunction with the results of all the groups to generate dynamic estimates for the effectiveness of the chosen environmental policy instruments.

### 3 Expected research results

- A general assessment publication of the current policies, their spatial and temporal effectiveness and boundary conditions.
- Analytical tools for investigating the influence of temporal and spatial scale on ecological efficiency.
- Multidimensional indicators of ecological efficiency and effectiveness.
- Improved utilisation rates of wastes and by-products in the three cases.
- Recommendations for environmental regulation or de-regulation promoting resource cycle closure.
- Systemic model for test cases for estimating effectiveness of environmental regulation.

#### 3.1 Second year results

##### Publications:

Dahl, O., Nurmesniemi, H., Pöykiö, R.. "Sequential extraction partitioning of metals, sulfur, and phosphorus in bottom ash from a coal-fired power plant", *International Journal of Environmental and Analytical Chemistry*, 88 (2008) 61-73.

Dahl, Olli; Poykio, Risto; Nurmesniemi, Hannu. Concentrations of heavy metals in fly ash from a coal-fired power plant with respect to the new Finnish limit values. *Journal of Material Cycles and Waste Management* (2008), 10(1), 87-92.

Eloneva S., Teir S., Salminen J., Revitzer H., Kontu K., Forsman A.-M., Zevenhoven R., Fogelholm C.-J., 2008a. Pure calcium carbonate product from the carbonation of a steelmaking slag. Presented at Accelerated Carbonation for Environmental and Materials Engineering (ACEME), 1-3 October 2008, Rome, Italy.

Eloneva S., Teir S., Revitzer H., Salminen J., Fogelholm C.-J., Zevenhoven R., 2008b. Reduction of CO<sub>2</sub> emissions from steel plants by using steelmaking slags for production of marketable calcium carbonate. Presented at the 3rd International Conference on Process Development in Iron and Steelmaking, SCANMET III, 8-11 June 2008, Luleå, Sweden.

Eloneva S., 2008. Co-utilization of CO<sub>2</sub> and steelmaking slags for precipitated calcium carbonate production. Licentiate Thesis. Helsinki University of Technology.

Heikkinen et al., supervisor of the Bachelor's works:

- Hanhisuanto, E., Tornion terästehtaan kuumavalssaamon alitteen sisäisen kierrätyksen mahdollistaminen. Kandidaatintyö, Oulun yliopisto, Oulu 2008. 23 pp. (In Finnish)
- Vasankari, A., Kuumavalssaamon jäähdytysjärjestelmän lietteet. Kandidaatintyö, Oulun yliopisto, Oulu 2008. 23 pp. (In Finnish)

Heino, J. and Virtanen, E. (eds.). Summary and further acts of the ProDOE –workshop arranged at Ruukki Raahe Steel Works at 10 – 11<sup>th</sup> of October 2007. Oulu 2008. 78 pp.

Heino, J. Harjavalta industrial park as an industrial ecosystem to increase regional and global sustainability. Environmental management in networks course. University of Jyväskylä 18.3.2008. 26 pp.

Heino, J. & Dahl, O. Teollisen ekologian soveltaminen Perämerenkaaren metallurgiseen teollisuuteen – Haasteet ja mahdollisuudet. Esitelmä Suomen Teollisen ekologian seuran järjestämässä "Materiaalivirrat ja ilmastonmuutos" seminaarissa 28.4.2008. (In Finnish)

Heino J., Watkins G., Makkonen, H., Koskenkari T., Leinonen, V., Dahl, O., Fabritius, T. & Virtanen, E. Industrial ecology applied to metallurgical, chemical and pulp and paper industries around the Bothnian Arc. Scanmet III Conference 8-11 June 2008, Luleå, Sweden. P. 243 – 252. (Conference paper and J. Heino's oral presentation)

Heino J., Mälkki, H., Leinonen, V. & Koskenkari, T. Harjavalta industrial park as an example of an industrial ecosystem when developing local and regional sustainability. 14<sup>th</sup> Annual International Sustainable Development Research Conference September 21-23, 2008, India Habitat Center New Delhi, India. 21 pp. (Conference paper and H. Mälkki's oral presentation)

Heino, J. Common solution around Baltic sea. Nordic Recycling Day IV in Luleå 7<sup>th</sup> – 8<sup>th</sup> of October, 2008. (Oral presentation and digital presentation material in seminar proceeding)

Heino, J, Koskenkari, T., Leinonen, V. & Mälkki, H. Harjavalta eco-industrial system. Industrial Ecology –course. Oulu 2008. University of Oulu. 25 pp.

Erkki J. Hollo, Matias Forss, Mari-Linda Harju-Oksanen, Outi Helander, Jaakko Kanerva, Miisa Karjalainen, Suvi-Tuulia Leppäkorpi, 2008. ”YMrä 23/2008 Katsaus eräiden EU-maiden jätelainsäädäntöön”

Hukkinen, J. (2008) *Sustainability Networks: Cognitive Tools for Expert Collaboration in Social-Ecological Systems*. London: Routledge (<http://www.routledgeconomics.com/books/Sustainability-Networks-isbn9780415461603>).

Hukkinen, J. (2008) ”Viisaita suosituksia metsähallinnolle” (”Wise recommendations to the forest administration”) in Finnish, in T. Määttä, A. Kumpula, K. Kokko, R. Sairinen, J. Similä (eds) *Ympäristöpolitiikan ja -oikeuden vuosikirja 2008*, Joensuu: Joensuun yliopisto, pp. 471-473.

Hukkinen, J. (2008) “Hot Topic: Which way scientific publishing?” *European Society for Ecological Economics Newsletter*, Summer (<http://www.euroecolecon.org/newsletter-summer08.htm>).

Hukkinen, J. (2007) ”Book reviews,” *Environmental Values*, Vol. 16, No. 1, pp. 129-132 (review of *Understanding Institutional Diversity* by Elinor Ostrom, Princeton: Princeton University Press, 2005).

Hukkinen, J. (2007) “Editorial: The evaluation crisis,” *European Society for Ecological Economics Newsletter*, December (<http://www.euroecolecon.org/newsletter-dec07.htm>).

Hukkinen, J. (2007) “Hot topic: Finland—Nuclear heaven?” *European Society for Ecological Economics Newsletter*, February (<http://www.euroecolecon.org/newsletter-feb07.htm>).

Kinnunen, M. (Wierink), Oja, M. and Heiskanen, K.: Recovery of Scrap Metals from MSWI bottom ash Using Physical Separation Methods, Proceedings of XXIV International Mineral Processing Congress Beijing China 24-28 September Volume 3, pp. 3565-3581

Mälkki, H., Heino, J. & Pajunen, N. Sustainable development in the Harjavalta industrial park. Lahti Science Day, November 25, 2008. Poster presentation.

Rinne J., 2008. CO<sub>2</sub> sequestration potential of industrial by-products and waste materials in Finland. Master's thesis. Helsinki University of Technology.

Salmi, O. (2008): Drivers for adopting environmental management systems in the post-Soviet mining industry. *International Environmental Agreements: Politics, Law and Economics* 8(1): 51-77.

Salmi, O.H. (2008): Science, Sulphur and Sustainability: Environmental Strategies of Mining in the Russian Kola Peninsula. Doctoral Dissertation. Helsinki University of Technology, Faculty of Engineering and Architecture, Department of Civil and Environmental Engineering. Espoo: TKK Dissertations 137.

Warsta, M.: Ympäristölupajärjestelmä - Analyysi nykytilasta ja kehittämismahdollisuuksista. Doctoral thesis. Edita Publishing, Helsinki 2008.

Warsta, M.: Ympäristölupajärjestelmän kustannustehokkuudesta toiminnanharjoittajan ja hallinnon näkökulmasta - Esimerkkitoimialoina metsäteollisuus ja turvetuotanto. *Ympäristöjuridiikka* 2/2008 (referee-article).

Warsta, M.: Ympäristölupajärjestelmä ja yhdenvertaisuus – Toiminnanharjoittajien tasapuolisesta kohtelusta. Ympäristöjuridiikka 1/2008 (referee-article).

Wierink, M. & Heino, J. ProDOE and Bothnian arc industrial ecology enterprise? Article in Materia magazine 4/2008, pp. 40 – 42.

## **4 Activities of The Research Project**

### **Visits:**

Jyrki Heino's participation in Process integration seminar "Nordiska lösningar – Finns dom" on January 2008 at MEFOS (Luleå/Sweden),

Jyrki Heino's participation in "Materiaalivirrat ja ilmastonmuutos" seminar arranged by Suomen Teollisen ekologian seura 28.4.2008,

Prof. Jouko Härkki's and Jyrki Heino's participation in Scanmet III Conference on 8-11 June 2008, Luleå, Sweden,

Preliminary contacts of prof. Olli Dahl, Mikko Angerman and Jyrki Heino with Bothnian arc association through city authorities of Oulu,

Prof. Jouko Härkki's and Jyrki Heino's participation in Nordic Recycling Day IV in Luleå 7<sup>th</sup> – 8<sup>th</sup> of October, 2008. Heikkinen and Heino acted also in the planning and arranging team of the seminar together with Caisa Samuelsson from Luleå University of Technology, who where most responsible of the arrangements.

Prof. Jouko Härkki' and Jyrki Heino's participation in Lainsäädäntö, ympäristö ja kierrätys –osioon FinnMATERIA – kongressissa Jyväskylässä 12.–13.13.11.2008. Prof. Jouko Härkki acted also in the planning commission of the section mentioned above.

Pajunen, M. and Mälkki, H. Oral Presentation in The 8th International Conference on EcoBalance Dec. 10.-12., 2008, Tokyo, Japan. "Legal, sustainable and economical way to control Industrial by-products"

Warsta, Matias. YHYS-seminar, 20-21 November in Joensuu, Finland. Presentation: "Ensuring adequate waste management: Is financial security the right tool and how should it be regulated?"

Gary Watkins and Eila Salomaa, presentation "Environmental Performance and the Cost of Water Pollution Control Compliance in Industry", 14th Annual International Sustainable Development Research Conference, New Delhi, India, September 21-23 2008.

Maria Wierink's Oral Presentation in XXIV International Minerals processing congress (Recovery of Scrap Metals from MSWI bottom ash Using Physical Separation Methods), 24.-28.9.2008, Beijing, China

Maria Wierink's Oral Presentation in STaR Final Technical Feedback Meeting (Sustainable transport solutions) 19. – 22.10. 2008

## **5 Progress of The Research Project**

### **5.1 Professor. Dahl's research group**

Identification and investigation of industrial residue streams for innovative use/reuse .

Concerning research on industrial residue streams concentrating on the fibre and metals industries. Achieve advances through the identification of specific candidate material streams for further investigation:

- Identification of the limiting factors hindering the current utilization of significant material streams identified, including characterizing stream impurities.
- Investigation of the technical feasibility of innovative uses and ways to overcome utilization issues presented by impurities or residue characteristics.
- Development of new ideas for new processes and new ways of connecting existing processes, especially in the fibre cycle (and also with the steel industry), through investigating ways of reducing impurities, changing compositions or finding new ways of combining material streams.

Progress:

- Fibre partners secured – Stora Enso Oyj- pulp and paper mills located in and around Oulu and Kemi. Veitsiluoto (Kemi) and Oulu Mills are cooperation sites.
- Research focus is the “Investigation of alkaline and other mill residues as activators and fillers for fibre reinforced blast furnace slag cement based concrete products and cementitious matrices”
- Main residue testing and analysis work to be carried out Summer/Autumn 2009 at Oulu Mill and at Otaniemi by MSc student M. Mäkelä.
- At least 4 academic papers are in preparation for 2009.

Work completed in 2008:

- Stora Enso Mill visits and candidate material stream discussions regarding the investigation of residue qualities, identification of utilization issues, chemical and physical analysis work to be undertaken as well as consideration of options for intra-industry utilization/intensification options.
- Identification of Bothnian Arc as a research focus by IMS sub Group.
- Initial literature research on residual material properties and current material utilizations in the pulp and paper sector. Background papers on the pulp and paper sector for ProDOE IMS Research Group consumption.
- Book Publication – Background research for both ProDOE and the production of the second fully updated edition of the book Papermaking Science and Technology, Environmental Management and Control Volume 19 (FAPET) ISBN 978-952-5216-30-1 (2008). Olli Dahl was editor and contributed to all Chapters. Gary Watkins wrote or contributed to the following:
  - Chapter 2 - Environmental Controls, Hynninen, P. & Watkins, G., pp. 20-46
  - Chapter 3 - Environmental Permits in Industry, Hynninen, P., Watkins, G., pp. 48-54
  - Chapter 8 - Solid and Liquid Wastes, Hynninen, P., Dahl, O., Watkins, G., pp. 138-165
  - Chapter 9 - Other Impacts and their Reduction, Watkins, G., pp. 167-176
  - Chapter 10 - Tools for Environmental Management, Watkins, G., pp. 177-211
  - Appendix 1,2,3 and 4 Technical appendices, Hynninen, P. & Watkins, G., pp. 214-289

## **5.2 Professor Ekroos' research group**

1 doctoral dissertation, 1 conference paper and oral presentation, 1 poster presentation.

In Matias Warsta's doctoral thesis the main aim was to analyze how optimal the environmental permit system is for regulating certain types of installations especially from the administration's and operator's point of view. The efficiency of the procedure has been evaluated not only by the juridical methods but also from economic aspects.

The starting point of the Mari Pajunen's research has been careful analysis of the current legislation and policy in view of the industrial ecology. The aim is first to describe the policy targets, current situation and the rationale and reasons for the development by analysing relevant policies and instruments at national, EU- and global level.

## **5.3 Professor Fogelholm's research group**

During the last year, main focus was on finding the CO<sub>2</sub> sequestration potential of calcium rich industrial waste materials and by-products in Finland. That is, how much carbon dioxide could in theory be sequestered in these materials by mineral carbonation. The investigated calcium-rich materials may be classified to silicate minerals from mining industry and industrial wastes and by-products (Rinne J., 2008). One possibly suitable secondary raw material from mining industry is wollastonite (CaO –content ~48%) but the interest to utilize wollastonite in carbonation is small as it is utilized (In Finland) in other valuable applications. The most significant CO<sub>2</sub> emissions reduction potential of calcium-rich secondary raw materials was found to be in steelmaking slags (CaO –content 40-56%). Secondly best

emissions reduction potential was found to be in pulverized coal (PC) combustion ashes (CaO –content 2,9-5,5% ) and concrete wastes (CaO in cement ~64 %), this potential was rather based on the large amount of material produced annually. Significant CaO –content were found in wood ashes (in this; spruce CaO –content ~37 %), cement kiln dust (CKD) (CaO –content ~38 %) and de-inking ashes (CaO –content ~38 %) however the annual production of these wastes is quite small and as a result also the CO<sub>2</sub> emissions reduction potential. Other calcium-rich industrial wastes and by-products which may be suitable for carbonation according to their calcium -content are municipal solid waste incinerator (MSWI) –ashes, sewage sludge ashes and peat ashes. In all, calcium-rich industrial wastes and by-products have an annual reduction potential of about 1 Mt CO<sub>2</sub>. The steady production, higher reactivity compared to magnesium-rich silicates, the possibility of manufacturing a valuable end-product precipitated calcium carbonate (PCC) and the local CO<sub>2</sub> emissions reduction may improve the interest of carbonating calcium-rich wastes. However, this amount is suspect to many uncertainties linked on the availability and possible carbonate content. Further research and development is needed to find out whether suitable carbonation process can be found or invented for these materials.

The actual CO<sub>2</sub> sequestration potential depends on how effectively the calcium and magnesium components extract from the secondary raw material, how effectively these components react with CO<sub>2</sub> and how much energy is required for this process. Possibility to extract calcium from few of these materials by using the method that has previously been found to be promising (Eloneva et al, 2008a) was also investigated. Tested industrial byproducts were three different steelmaking slags, serpentinite and two samples from concrete industry. The best result was achieved with AOD – process slag, from which 56 – 60 % of calcium was selectively extracted. While mineral carbonation method based on these solvents could be suitable for AOD slag, other methods are needed for the other investigated waste materials.

## **5.4 Professor Heiskanen´s research group**

The research work has focused on the survey of the material streams of selected industrial ecosystems, particularly Kokkola industrial park and possibilities on linking the by-product streams with other industrial ecosystems within the area, such as Boliden Rönnskär plant (Sweden) and Outokumpu Tornio stainless steel factory.

Researcher Maria Wierink completed 60 credit points of post-graduate studies required for doctoral studies.

Young author award of the XXIV International Minerals processing congress to Maria Wierink.

### **International post- graduate training (M. Wierink)**

- WISE- Waste in Social Environment Training Course, Monschau, Germany, 10.- 14.3. 2008, Core theme: Substance cycle waste management.
- STaR City of the Future- Integrated Sustainable Systems, Training Course 2, Sector A. Obidós, Portugal, 6.- 11.4. 2008, Core theme: Integrated Sustainable Systems
- WISE- Waste in Social Environment Training Course, Dresden, Germany, 16.-20.6.2008, Core theme: Environmental impacts
- WISE- Waste in Social Environment Training Course, Malta, 6.- 11.10.2008, Core theme: Secondary raw materials
- STaR City of the Future- Integrated Sustainable Systems, Final Technical Feedback Meeting 19.-22.10. 2008
  - These programs are 100% funded by Marie Curie Actions of EC

### **Maria Wierink´s Participation in**

- Finnish Association of Mining and Metallurgical Engineers Seminar on beneficiation and utilization of industrial wastes and by products, 6.11.2008 Espoo, Finland
- FinnMATERIA Congress on Legislation, Environment and Recycling 12-14.11.2008, Jyväskylä, Finland
- YHYS Congress Challenges of European Environmental Policy: from Environmental Integration to Global Responsibility and Better Regulation 20.-21.11.2008, Joensuu, Finland

## **5.5 Professor Hukkinen´s research group**

1 book (monograph), 1 doctoral dissertation, 1 peer review paper, 1 conference parallel session, 1 Prodoe project internal workshop.

### **Prof. Janne Hukkinen**

- Reviewer of scientific books: Routledge, London, textbook proposal in ecological economics, 2008.
- Reviewer of scientific articles: Human Organization (Society for Applied Anthropology) 2008

- Doctoral dissertation opponent: Ms Kaisa Raitio, University of Joensuu. “You can’t please everyone”— Conflict management practices, frames and institutions in Finnish state forests. 2008
- Doctoral dissertation evaluator: Mr Petrus Kautto, Helsinki School of Economics. Who holds the reigns in Integrated Product Policy? An individual company as a target of regulation and as a policy maker, 2008; Ms Ulla Rosenström, University of Helsinki. Sustainable development indicators: Much wanted, less used? 2007-8
- Organized internal Prodoe writing workshop in Lahti 5 March 2008
- Lecture on the Challenges of doing interdisciplinary research, Helsinki Institute of Science and Technology Studies (HIST) and Finnish Society for Science and Technology Studies annual seminar, Helsinki 26 February 2008
- Invited expert participant in ERA NET SKEP Workshop on “Environmental impacts of the convergence between nanotechnologies, biotechnologies, information and communication technologies and cognitive sciences”, Paris 28-29 February 2008
- Lecture at the Finnish Graduate School of Science and Technology Studies Summer School, “The Art of Co-Authoring a Good Paper”, Espoo 26-27 May 2008
- Lecture at Bright 2008: Europe as a Knowledge Society, University of Helsinki, 16 August 2008: “From interdisciplinary work to new knowledge on social-ecological systems”
- Lecture at FinnMateria 2008, Jyväskylä, 12 November 2008, “Governance of the Bothnian Arc Industrial Ecosystem” (with Olli Salmi and Nani Pajunen)
- Lecture at Ministry of the Environment UUMA Seminar, Espoo, 25 November 2008, “End of waste for mineral residues: Future visions in European context” (with Olli Salmi and Nani Pajunen)
- Inaugural lecture for the professorship in environmental policy at University of Helsinki, 3 December 2008: “Environmental expert: Master of facts, arbitrator of values or something else?”
- Invited expert participant to VTT workshop on Public Sector Innovations, Espoo, 8 December 2008

#### Olli Salmi

- Reviewer of scientific articles in 2008: Journal of Environmental Management (Elsevier) and Ecological Economics (Elsevier)
- Chairperson of the parallel session *Transnational governance of material recycling* at the YHYS Conference “Challenges of European Environmental Policy: From Environmental Integration to Global Responsibility and Better Regulation, Joensuu, Finland, 20-21 November 2008.”
- Lecture at the YHYS Conference (with Janne Hukkinen, Mari Pajunen, Maaria Wierink and Jyrki Heino): *Industrial ecosystems and environmental governance at different spatial scales: The case of the Gulf of Bothnia*. Joensuu, Finland, 20-21 November 2008.

## 5.6 Professor Härkki’s research group

According to research plan the researcher has with the help of many mutual meetings acquainted the research group of ProDOE and especially in the Innovative use of material streams (IMS) subproject to utilize to the joint expertise in research group maximally. It has been made a very ambitious publication design concerning both Botchian arc industrial ecology enterprise within IMS and new feasible utilisation possibilities beyond the conventional usage of copper and nickel slags, which belongs to the sphere of responsibilities of the Laboratory of Process metallurgy. Also information and networking got from other ongoing projects in the Laboratory of Process metallurgy will be utilized.

As promised in original ProDOE application to get additional funding it has been made a very big and innovative application concerning Bothnian arc industrial ecology enterprise, where the main target is to improve material and energy efficiency through both intra and inter company development work utilizing the unutilised energy and material residues from Finnish and Swedish metallurgical, chemical, and pulp and paper industries around the Bothnian Arc region. At this moment the ProDOE group is thinking, where the additional funding will be applied.