March 23, 2004

Evaluation of the Competence Centre for Environmental Assessment of Product and Material Systems, CPM,
at Chalmers University of Technology, Gothenburg

1. Preface, Methodology, and Acknowledgement

On Monday, March 22, 2004, two of us, the scientific experts of the evaluation team, Steven Frysinger and Atsushi Inaba were briefed by the Centre Director, Peter Lysell, project leaders, graduate students and industrial partners of the Competence Centre for Environmental Assessment of Product and Material Systems, CPM, on the scientific progress and range of projects within the Centre. In the morning of March 23 the entire review committee received information on the research and general issues concerning CPM by the Director, the Vice Rector of Chalmers University of Technology, Johan Carlsten, the Dean of the Section for Environmental Engineering, Oliver Lindqvist, senior scientists, project leaders, and industrial partners. In addition to these hearings, this evaluation is based on the written report to the international evaluation team, including reprints and manuscripts.

We appreciate the high quality of the presentations given during the evaluation. We were very pleased by the openness and frankness shown in discussing technical as well as strategy issues with all of us, as members of the evaluation team.

We would like to thank the whole CPM team for the efforts they made in preparing these two days of briefings. We also thank Carl Naumburg and Staffan Hjorth of VINNOVA for the invitation and their assistance in all aspects of the review.

2. Technical and Scientific Outcomes

Major Technical Achievements. Implementation.

CPM has broadened its scope from Life Cycle Assessment (LCA) to include a suite of additional methods addressing sustainable development: Life Cycle Costing (LCC), Environmental Risk Assessment (ERA), Design for Environment (DfE), Environmental Prioritization Systems (EPS), Strategic Systems Analysis, and Environmental Management Systems (EMS). Within these areas, CPM has developed some very effective tools. Some of the most mature work, addressing the life cycle inventory process, has evolved in the third phase and has strongly influenced the development of an international standard (ISO 14048). The Industrial Environmental Informatics (IMI) department of Chalmers, working very closely with CPM, is producing prototype tools to evaluate the environmental impacts of industrial products. Starting with SPINE data, these will widely support management decision-making concerning product life cycles in industry.

The 3rd phase of CPM has seen continued progress in other areas as well. For example, the important EPS continues to be studied, supported, and applied. Likewise, eco-efficiency and environmental indicators developed at CPM have good quality and high availability for industry. The Type III Eco-label, which establishes the international trend on eco-labelling, is one of the several success stories demonstrating the utilization of CPM's achievements.

Major Scientific Achievements and Productivity

CPM's international activities on ISO/TC207/SC5 (LCA) have led the international movements on environmental management of industry. Although seemingly aimed at the standardization of their academic products, CPM's academic qualities are significant and the targets will certainly continue to gain worldwide acceptance in the near future.

The EPS method of life cycle impact assessment is one of the honoured achievements as the pioneer of the methods involving the social consensus on decision making on the environmental issues using "willingness to pay." While it must be strengthened by being used more in Swedish industry through industrial cooperative studies, especially in the field of risk assessment of chemical substances, this system continues to be a cornerstone worldwide. CPM has also contributed to the scientific, engineering, and management literature through dozens of publications and presentations.

Education and Training

CPM's contribution to education at Chalmers is overall very good. In the third phase the relationship with Chalmers was substantially improved. The development of the Industrial Environmental Informatics (IMI) department is direct evidence that the Centre is having a significant, positive impact on the academic environment in which it resides. This department was created in the university in response to the remarkable success of the informatics effort within CPM, as well as the clear importance of informatics to industrial ecology.

The Environmental Systems Analysis (ESA) department of the university, which is also closely allied with CPM, directly contributes to the education of undergraduate and graduate students through a series of courses relating to sustainable development: Environmental Technology (compulsory), Environmental Systems Analysis, Environmental Management, Technology Evolution, Life Cycle Assessment, and Ecological Building. The first of these courses seats approximately 70 students per year, while the rest (which are elective) attract approximately 30 students each per year.

CPM was also instrumental in the education of several Master, Licentiate and Ph.D. students. Students especially benefit from the industrial connections afforded by the Centre. Access to companies would otherwise be difficult and quite limited, preventing students from carrying out applied research in the context of real world problems. Instead, CPM allows students to work on problems actually faced by industry, and directly with industrial staff and data.

The existence of CPM at Chalmers facilitated the creation of the Chalmers Environmental Initiative (CEI) in the year 2000, in which seven professorships and their research programs were established, and thus was a factor in Chalmers being elected to the Alliance for Global Sustainability (AGS), joining ETH (Switzerland), MIT (USA), and University of Tokyo (Japan) in this partnership.

Finally, it can safely be concluded that CPM was a significant factor in the decision taken by Chalmers to offer an international master's degree in Industrial Ecology, to begin in the autumn of 2004.

Conclusions and Recommendations

Tremendous progress has been made since the mid-term review of CPM, and great opportunities for continued success are evident. There are some relatively specific actions which CPM should consider taking during Phase 4 in order to continue its improvement:

- The activities of CPM on environmental management in industry must be continued. Their academic products must lead the international trend.

- In the context of automobile manufacturing, attempt to advance the state of the art of the International Material Data System (IMDS). At first blush it seems that LCI@CPM might be a superior replacement for this system.

- Sustainable production and consumption are two pillars for sustainability. Although CPM has focused mainly on the production side, it should look further at the consumption side in the future, because their academic products (such as eco-efficiency, environmental indicators and Type-III Eco-labels) must be seen by consumers and must be accepted.

- CPM seems to consist of two groups. One is in the area of Industrial Environmental Informatics and the other is the area of Sustainability. The former should strengthen its connections to Computer Science, and the latter should be linked to the works of IPCC in the field of climate change and to the EU and OECD works in the field of risk assessment of chemical substances.

- Consider developing academic curriculum components in the informatics area, linking the IMI, ESA and computer science departments of Chalmers. This could take the form of a concentration/minor in either the computer science or environmental management programs, or perhaps even become a bachelor's degree program of its own. Besides producing a valuable cohort of "bi-lingual" graduates, this might also enhance the productivity of CPM in informatics.

3. Industrial Benefits. Impact on Industrial Partners.

Industrial Interaction and Involvement in Centre Activities

CPM currently has eleven active industry partners, from different sectors (automotive, chemical, pharmaceuticals, manufacturing, forest, aeronautical), representing a mix of medium and large Swedish and international companies. Industry supports the Centre financially mainly through in-kind contributions, supplemented by small to modest cash contributions. As appreciation of knowledge and methodology from CPM increases and results are transferred to commercial products and practices, it is appropriate for the cash contributions to increase. All industry partners enthusiastically support the CPM operational mode and, very significantly, the impact of the Centre on product LCA from an environmental point of view and on national and international standardization.

It was evident, based on the written documentation submitted and the oral presentation given to us, that the Board, industry partners and academic researchers have developed a shared, well understood and continuously developing vision of the overall objectives and technical themes of CPM. These are organized along the following long-term goals:

- prevent and decrease environmental impact associated with products,
- gather and reinforce the Swedish competence within sustained product development at a high international level
- provide industry and society with relevant methods and support for implementation of environmental aspects in decisions regarding products and materials.

The Board and leadership of CPM are to be commended for overcoming the difficulties encountered during stage three and for establishing a new and more effective organizational structure. The benefits of the new operational procedures were quite evident to us. They allow direct contact between the Director and the project managers, resulting in tangible improvement in efficiency, commitment and productivity. The Planning Group is a well functioning technical management instrument that enables efficient consideration of new project ideas and proposals as well as careful evaluation of existing projects. The Board and the Planning Group work synergistically. The Board makes all final decisions in line with overall goals and budget. Broad participation by industry in these two bodies ensures efficient and timely programme information, dissemination and opportunities for role selection (i.e. whether to become actively involved in a project or merely follow its progress).

CPM is also to be commended for persistent development of operational principles that foster close collaboration between academia and industry. Industry partners participate actively in all projects of CPM, and also contribute substantially to planning, strategizing, dissemination of information and education.
Policies implemented in order to facilitate and enhance knowledge and technology transfer are:

- active collaboration between industry personnel and academic researchers,
- PhD candidates employed by industry (Industry PhDs),

- organization of tailored workshops for the exchange of results, experiences and knowledge between academic researchers and industry personnel,
- sustained efforts to involve industryin the direction and projects of CPM,
- sustained efforts to allow CPM to influence business policies and procedures regarding life-cycle environmental issues,
- availability of tools and methodologies to industry practitioners,
- availability of data and case evaluations from industry,
- active industry participation in University education and courses,
- active dissemination of results via international standardization organizations,
- access for industry partners to results and knowledge through a redesigned Internet web site.

There was ample evidence of widespread mutual knowledge and technology transfer between academic researchers, students and industry scientists. Industry and academia collaborate towards developing "sustainable production" into a rigorous and quantifiable subject matter, and also in establishing international standards for representation, analysis and decision-making when environmental issues are taken into account. The effort to systematically assess the impact that CPM has had on its industry partners is an excellent idea and should be pursued with additional emphasis towards linking product/process economics to environmental issues and society.

Significant benefits to industry reaped from CPM activities were reported to be:

- increased knowledge of and expertise in database formats and tools,
- improved methods for performing LCA and assessment of life-cycle environmental impact,
- improved tools for communication with shareholders,
- open exchange of information, knowledge and results between member companies,
- collaboration with academic experts that are leading research and development in several areas,
- common focus on sustainable development (that begins to emerge as a market differentiator for products),
- gaining knowledge and expertise in integration of LCA results and environmental issues in product and process development,
- access to qualified students.

It was clear to us that industry partners have successfully transformed from the initial status of "believers" to "knowledgeable" practitioners and collaborators in the CPM programme with overall focus on sustainable production. Most significantly, several companies have realized that assessments of the economic impact (mainly costs) of environmental considerations on their products and processes need to be strengthened and expanded by developing efforts on the benefit side of economics.

Furthermore, stronger links with mainstream engineering product and process design need to be established. In addition to drawing benefits from the more advanced state of industrial systems engineering tools, standards and processes, this will result in increased importance and visibility. CPM has made initial efforts in this latter direction, as

evidenced by the project "Design for Recycling", which should be further developed and intensified.

Implementation of Results: Technology Transfer, Commercialization, Success Stories

The technical theme of CPM is new, and one that is regarded, correctly, as infrastructure and strategic investment by industry partners. Thus, naturally, direct commercialization into products is not yet achievable. All current industry partners are using the knowledge, techniques and methods gained for improving and enhancing their production processes, and not for the commercialization of products centered on methods and techniques developed by CPM. As CPM marches in the future there will be a need for involving additional companies (*e.g.* software companies) that will be interested in developing commercial products and services based on CPM research.

With this understanding there have been substantial accomplishments in knowledge and technology transfer from the CPM programme. Industry partners have been "educated" in the value of methods such as LCA and have become active practitioners. Ample evidence was presented of the establishment of internal groups on LCA by industry partners, as well as of critical influence on product design and technology selection due to the inclusion of environmental impact analysis and CPM research and development tools.

Through participation in CPM, SCA substantially increased its knowledge and competence in environmental impact analysis: structured data handling and documentation formats, using SPINE, emergence of the ISO/TS 14048 standard, methodologies for handling forest industry environmental data, experience for environmental product declarations. This resulted competence for development and implementation in three company mills of an internal tool "Hermes", evaluation and use of LCA in SCA hygiene products, and increased visibility and appreciation of LCA and similar methods within the entire company. A more recent benefit has been the current joint project on "policy controlled environmental management" which aims at further integration of environmental aspects into the entire operation of the company.

ABB has also increased substantially its knowledge and competence in this area through participation in CPM. This has resulted in the development of efficient tools for representing and analyzing the environmental impact in the entire production systems. ABB´s Sustainability Tool-Box is an important and critical development based on these gains and has been used in numerous cases and product decisions within the company (ample and specific product information and case history was provided). More significantly, requests by the marketing department based on the development of environmental impact into a substantial market differentiator, the company has initiated efforts to incorporate economic benefits of environmental assessments into product design.

Akzo Nobel is a key participant in the large EU project DANTES, which is focused on developing and demonstrating tools for environmental assessment and communication. This is mainly due to their participation in CPM. Implementations are to become strategic tools for industry and Akzo Nobel in particular.

Many present and former CPM industry partners, ABB, Akzo Nobel, Bombardier Transportation, Ericsson, SCA, Vattenfall, Volvo Car, Stora Enso, have implemented the SPINE data documentation format.

CPM initiated the international standardization of a format for LCA data documentation, ISO 14048. Many of its industrial partners supported this development by sharing experiences with the international community of using the SPINE format.

CPM was actively involved in the development and further enhancement of the format for Environmental Product Declarations (EPD). The Centre has also developed tools for comparing different product categories: interpretation keys for EPD and type III labelling. The CPM partners ITT Flygt, ABB, Akzo Nobel, Volvo AB and Volvo Car Corporation, are now using EPDs in communications with customers and other stakeholders.

Several of the CPM industry partners, e.g. SCA, ABB, Akzo Nobel, Volvo AB, have integrated the holistic approach promoted by CPM into their product and R&D stage gating processes. Others are on their way of doing so. This further shows that the commercialization of CPM ideas take place through "cultural" and "infrastructural" changes rather than through traditional, direct product development of the research results.

Conclusions and Recommendations

CPM has established a highly successful industry-university collaborative environment in a technical area critical to many sectors of Swedish industry and Swedish society at large. CPM research results have clearly changed industry "culture" and have resulted in the development of new strategic and infrastructure processes by its industry partners and the international industrial community.

We would like to offer the following recommendations:

- Develop further the linkage between production economics with environmental issues, not only on the cost side but also on the benefits side (i.e. economic value added).

- Develop further and strengthen the linkage of LCA and other environmental impact systems to systems engineering methods and techniques, such as design and requirements engineering, total cost of ownership.

- Bring in as Centre partners many more small and medium size companies in an effort to improve the current company mix and in order to induce direct product commercialization.

- Bring in as Centre partners consumer companies and associations in an effort to enhance user education and valuation of the research results and impact of CPM.

- Attempt to quantify the financial benefits member companies accrue through participation in CPM. An initial subjective study has already begun, but conducting economic "value added" analyses can enhance this.

- Try to identify and report the "secondary effect" of CPM on industry, i.e. non-member companies that are implementing and/or benefiting from CPM results. It is likely that CPM has created a larger worldwide effect than is immediately evident.

4. Present Standing of the Centre

International Ranking and Attractiveness

The leading position of Swedish contributions to environmental system engineering (ESE) and assessment is internationally recognized. The role played by CPM in creating this position is very significant; in particular through the developments of methods and tools for gathering, structuring and communication of LCA data, the creation of the SPINE@CPM Swedish national LCA database and the concomitant conversions to ISO standardized formats. These contributions imply that CPM methods have influenced research in ESE internationally to a considerably larger extent than is explicitly recognized internationally. For example, as brought forward by one industrial representative, Swedish acquirements of commissions in LCA from EU are significantly dependent on CPM work. Another example is the inclusion of Chalmers in the Alliance for Global Sustainability (AGS).

The scientific recognition of CPM in association with Environmental Systems Analysis (ESA) at Chalmers has grown steadily, by the association of an increasing number of senior academic researchers with ESA and CPM. CPM and other Chalmers researchers also participate actively in several large EU programmes to which the CPM methods and tools give significant contributions.

CPM has reported and disseminated methods based on its results in the usual way at international conferences and through scientific papers and reports, and also very recently through a textbook by two of its senior scientists.

The industry/academia relationship represented by CPM is internationally unique and exemplary. In view of this, international exchange of researchers, seminars at CPM etc appear to have been surprisingly limited. We repeat the recommendation from the previous evaluation that CPM fosters input from and contacts with international research by establishing an International Advisory Board.

The Centre as a National Asset. Critical size.

The way CPM has endeavoured to close the gap between academic research on ESI and industrial LCA, LCC, assessments of sustainability etc. through open exchange of information, knowledge and results between researchers and member companies is internationally unique. CPM is particularly significant in addressing not only environmental questions associated with the supplier/production/product chain but also

questions related to community, government and society in general. This has created a platform for the environmental assessment of industrial activities and technology and exchange of knowledge that is not easily available elsewhere and clearly is a very valuable asset for Sweden. The development of this platform and the demonstration of its viability is a very significant contribution of CPM to ESI in Sweden and its international standing in general.

CPM now engages a considerable number of senior scientists in its research. There are seven PhD students. It can be concluded that during the 3rd stage, core competence and size of CPM has developed into a research group of sufficient size to maintain projects of viable size and continuity, and to ensure productive internal exchange of research ideas. It was not evident to us to which extent CPM as such collaborates with other groups in Sweden engaged in research on similar areas.

Role and Impact of the Centre as a Part of the University

The Vice Rector of Chalmers said that Sustainable Development is defined as one of the main visions of research and education at Chalmers. In line with this, Chalmers has focused on environment by creating the Chalmers Environmental Initiative (CEI), into which CPM is being gradually integrated. CPM has a very important role in facilitating industrial involvement in this initiative. Some earlier problems associated with CPM have been overcome and CPM plays an important part in the education of students in environmental engineering.

It was clear to us that the active and creditable industry-university collaboration established by CPM has had several benefits for Chalmers, such as collaboration between several academic units (Environmental Systems Analysis, Geology, Industrial Environmental Informatics, Mechanical Engineering - Mechatronics, Physical Resource Theory, Gothenburg Research Institute) launching and financial support for the CEI and the invitation to join the international Alliance for Global Sustainability (AGS).

Chalmers has created a chair in Environmental Systems Analysis (prof. Anne-Marie Tillman) that has ensured the sustainable development of the scientific basis of CPM. Research at CPM now comprises about 30 % of the total research activity in ESA, but the impact of the Centre is probably even more important than illustrated by this number, through the intensive industrial contacts and input from industry it has created. The creation of the professorship has been of essential importance for the academic recognition of CPM. It was stated by the Dean Oliver Lindqvist that, in addition, the input from other professors to CPM should be strengthened.

As detailed above, CPM is actively engaged in development of undergraduate courses on topics in environmental engineering and participating in education of PhD students.

Conclusions and Recommendations

From its start, when CPM engaged few researchers of established academic standing, the Centre has grown into a research group of sufficient size and stability for sustainable development, engaging several senior scientists and producing results at the

internationally leading level. CPM is a national asset and an important part of the Chalmers Environmental Initiative, in particular in fostering intense industrial contacts. We note that in this respect a very satisfactory development of the Centre has taken place during the 3rd stage and we encourage further development along the same lines. As in the previous evaluation, we wish to make the following specific recommendation:

- Foster input from and contacts with international research and CPM´s attractiveness to international companies by establishing an International Advisory Board.

- Advance the CPM "brand" by taking credit for exports to the external world (e.g. ISO 14048, EPS). It seems that much of the Centre's work might be known but is not always attributed to CPM.

5. Future Prospects and Strategies

Technological-Scientific Prospects of Research Area. Focus of Future Research.

Environmental Systems Analysis in general and LCA in particular have developed very rapidly during the last decade, and CPM has followed this development by going from development of methods and tools to collection and structuring of data and then into implementation and communications issues, finally further broadening its scope into sustainability and commercialization. The Centre recognizes that the technological and scientific prospects of the area encompass a very wide range of topics and that for the future it is more important to find the correct areas to focus on than to find new areas for future research. This situation appears to be positive and encouraging.

Interests and Priorities of Centre Partners

Most of the supporting industries seem to regard activities at CPM as complementary to their own activities in environmental system analyses by creating databases, tools and methods. The industries have a strong interest that this activity should continue. Chalmers representatives all gave evidence of the importance of CPM activities as part of education in Environmental Engineering at Chalmers. They also stressed the importance of CPM as a bridge between academic research and industry in this area; the programme fits well within the CEI and there is a strong interest in maintaining the industrial contacts. Thus, there seems to be a general consensus between the partners on their interest in CPM with its action as a bridge between industry and academia as a priority and impact on education as a consequence of this.

Strategies for Stage 4

The Board and leadership of CPM have been considering the strategy both for stage 4 and the continuation of the Centre after that. As stated in the report, CPM has, indeed, accumulated a large body of knowledge and credibility about LCA and its results and a holistic perspective on environmental system analysis. CPM has been instrumental in moving the industrial partners from believing to knowing in their analysis of environmental impact, and thus has had real impact on process and product development.

The presentation of industry-university collaboration within CPM included a description of plans for the future of the Centre, which emphasized focusing of the programme (very much needed and recommended), more emphasis on implementation and assessment of investments made (excellent idea, also highly recommended), establishment of an improved connection between environment and economics (highly recommended) and stronger international collaboration. The overall vision for the future is that CPM is the natural partner in the evolution towards a sustainable society.

We agree with CPM representatives that this creates a strong starting position for planning of activities beyond stage 4. Work on a detailed strategy is well under way and we can only support this commendable activity. The Board and the Director also endeavour to increase the number of partners and are planning on a future financing of CPM based on major contracts (such as EU projects) and industrial support.

We are convinced that sustaining and enhancing the excellent accomplishments and modus operandi of CPM is essential for several sectors of Swedish industry as well as Swedish society at large, and that this is not possible without substantial public investment (by the government). This is also appropriate given the fact that society at large is a major beneficiary of the progress and results of CPM. Thus we wish to put forward the following strong recommendation:

- It is of vital importance that CPM in its future strategy seeks strong support not only from industry and Chalmers, but also from government funding sources. Only in this way can the long-term credibility and sustainable development of the scientific and technological level at CPM be guaranteed.

6. General Conclusions and Recommendations

During the 3rd stage CPM made excellent progress towards achieving the dual goals of a successful Competence Centre: becoming a well recognized and respected Centre of Excellence in research and education and at the same time maintaining an environment where collaboration between academics from different disciplines and collaboration between industry and academics is encouraged and thriving. This achievement is particularly impressive for CPM given the fact that its main technical competence represents a new field and in consideration of its initial state some eight years ago. Progress is remarkable in terms of broadening the scope of research, enlarging the academic staff and fostering excellent industrial collaboration.

We were particularly impressed by the effort taken by the industry partners in supplying information and implementing the results from the Centre in their environmental analyses.

We strongly support the efforts initiated by the CPM to ensure continuation of its activities beyond stage 4.

We wish to submit the following general recommendations:

- Attempt to quantify the financial benefits member companies accrue through participation in CPM. An initial qualitative study has already begun, but conducting economic "value added" analyses can enhance this.

- It is of vital importance that CPM in its future strategy seeks strong support not only from industry and Chalmers, but also from governmental funding sources. Only in this way can the long-term credibility and development of the scientific and technological level at CPM be guaranteed.

Gothenburg, March 23, 2004

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