# QANU Research Review
# Chemical Engineering 3TU

**QANU, November 2009**

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# Contents

# FOREWORD

This report follows the Standard Evaluation Protocol 2003-2009 for Public Research Organisations (SEP) that was developed by VSNU, KNAW and NWO. The purpose of this report is to present a reliable picture of the research activities submitted for this review and to give feedback on the research management and quality assurance.

The review Committee was supported by QANU (Quality Assurance Netherlands Universities). QANU aims to ensure compliance with the SEP in all aspects and to produce independent assessment reports with peer review Committees of international experts in the academic fields involved.

QANU wishes to thank the chairperson and members of the review Committee for their participation in this assessment and for the dedication with which they carried out this task.

We also thank the staff of the units under review for their carefully prepared documentation and for their co-operation during the assessment.

Quality Assurance Netherlands Universities

Mr. Chris J. Peels
Director

Dr. Jan G.F. Veldhuis
Chairman of the Board

# PREFACE

An evaluation of the quality of the science performed within the Chemical Engineering Departments at the three Universities within the 3TU-association requires much effort, first and foremost from all the members of the Departments that are being evaluated. The self-evaluation documents, which together with the very important personal contacts and discussions during the site visits form the basis of this report, are the result of long discussions and careful writing within the departments visited. This is the first and an important step in a process that should lead to a better insight of the strengths and possible weaknesses of a research group.

With the help of the self-assessment reports and the personal contact with the different representatives, the role of the Committee is not only to formulate an opinion on the research activity, based on the established rules of the assessment, but also to help in a constructively critical way to indicate the potential for further growth and improvement. This can only be done thanks to the commitment of the Committee members aided by the excellent logistic support of the QANU organization.

The present evaluation report is the result of such constructive interactions in a strong collaborative atmosphere between the respective universities and the Committee members. As Chair I want to thank all of them for the open, harmonious and hospitable way in which this operation could be brought to a good end.

Frans De Schryver
Chairman of the Assessment Committee

# 1. The review Committee and the review procedures

**Scope of the assessment**
The review Committee was asked to perform an assessment of the research on Chemical Engineering at the three technical universities in The Netherlands (3TU). The review covers the research in 34 programmes in the period of 2001 – 2007.

In accordance with the Standard Evaluation Protocol 2003-2009 for Public Research Organisations (SEP), the Committee's tasks were to assess the quality of the institutes and the research programmes on the basis of the information provided by the institutes and through interviews with the management and research leaders, and to advise how this quality might be improved.

Four additional questions were posed to the Committee:

- Will cooperation, adjustment and integration within the 3TU relation and the IDEA League strengthen the national and international position and visibility of the three TU's and participating research groups?
- TU Delft has defined four new research topics: energy, health, environment and infrastructures. The view of the Committee is requested on the appropriateness of the expertise within the field under review in relation to these four research topics;
- The Department of TU Eindhoven has defined a strategic vision for the mid-term (2008-2012) and invites the Committee to express her view on the proposed departmental research profile;
- The Department at Twente University would like to have an opinion of the Committee on the advantages and possible disadvantages of the organization of the ChE research in multidisciplinary research institutes based on past performance and future perspectives.

**Composition of the Committee**
The composition of the Committee was as follows:

- Prof. Dr. Frans De Schryver, Catholic University of Leuven (chairman of the Committee)
- Prof. Dr. Ir. Gerhart Eigenberger, University of Stuttgart
- Prof. Dr. Pierre Jacobs, Catholic University of Leuven
- Prof. Dr. Robert Jérôme, University of Liege
- Dr. Ludwik Leibler, ESPCI-CNRS
- Prof. Dr. Nava Setter, École Polytechnique Fédérale de Lausanne
- Prof. Dr. Bernard Witholt, ETH Zürich

A short curriculum vita of each of the Committee members is included in Appendix A.

Roel Bennink of the Bureau of QANU (Quality Assurance Netherlands Universities) was appointed secretary to the Committee.

**Independence**
All members of the Committee signed a statement of independence to safeguard that they would assess the quality of the institutes and research programmes in an unbiased and independent way. Any existing personal or professional relationships between Committee mem-

bers and institutes under review were reported and discussed. The Committee concluded that there were no unacceptable relations or dependencies and that there was no specific risk in terms of bias or undue influence.

**Data provided to the Committee**
The Committee has received detailed documentation consisting of the following parts:

- Self-evaluation reports of the institutes under review, including all the information required by the Standard Evaluation Protocol (SEP), with appendices;
- Copies of three key publications per research programme
- Bibliometric analysis carried out by CWTS.

**Remarks about the data provided**
The documents provided by the universities were an adequate basis for the evaluation, but the on-site discussions were essential and their importance in the overall process and the final outcome is a key factor.

**Procedures followed by the Committee**
The Committee used the rating system of the SEP 2003-2009. The meaning of the scores is described in Appendix B.

Prior to the first Committee meeting, each institute and research programme was assigned to two Committee members for review. A preliminary assessment was independently formulated on the basis of the self-evaluation reports and the key publications. Preceding the interviews, the Committee was briefed by QANU about the research assessment according to SEP. The Committee discussed the preliminary assessments. For each research programme a number of comments and questions were decided upon. The Committee also agreed upon procedural matters and aspects of the assessment. The site visits took place on April 19-24, 2009 (see the schedule in Appendix C) in Delft, Enschede and Eindhoven. After the interviews, the Committee discussed the scores and comments. The final assessments are based on the documentation provided by the institutes, the key publications and the interviews with the management and with the leaders of the programmes. The texts for the report were finalised through email exchanges. The final draft report was presented to the institutes for factual corrections and comments. The comments were discussed in the Committee. The final report was presented to the Boards of the participating universities and was printed after their formal acceptance.

# 1. General Remarks

This assessment of the research on Chemical Engineering in the three technical universities of Delft, Twente and Eindhoven (3TU), covering the period of 2001-2007, is based on information provided by these universities in their self-evaluation reports and during the site-visits. Through discussions with representatives of the research community, the Committee developed an impression of the research programmes presently running.

A first and most important remark is that on the whole the research quality of Chemical Engineering in the Netherlands is very good. Of the 34 programmes that have been reviewed, five were not scored because they were recently established, and of the remaining 29 programmes 16 have received the label 'excellent' for quality. Furthermore, the vast majority of the programmes, as well as the bibliometric indicators viewed of each of the departments of the three Universities, are generally well above world average.

A very interesting phenomenon that can be observed at each of the three universities is that there have been close interactions with industries not only internationally but also regionally, that have in many cases been initiated and often nourished by the mother institution. This can be seen with the polymer activities around Eindhoven, the microelectronics and IT start-ups generated around Twente, and the long-standing and very fruitful interactions between Gistbrocades/DSM and the TU Delft for more than a century.

Looking at the major Chemical Engineering disciplines, it is clear that the now almost classical areas of (bio)catalysis, biotechnology and polymer sciences are represented very well indeed. In addition, newer developments at the nano and micro level have also been embedded strongly in one or more of the three universities

As a rule, the Netherlands has a strong internationally leading position in macromolecular chemistry and polymer technology. Although very broad, the whole scope of research activities and expertise in the field is covered by world-renowned groups in the 3TU federation. Three major research directions are however worth being emphasized.
A special focus is placed on synthetic polymers as structural materials, with a continuously updated expertise in close relation with the ever more demanding novel technologies in terms of performances, sustainability and nanostructured materials. This is typically the case in Eindhoven, where this culture is practised at a very high level through chemical and physical routes and through processing, as well. An innovative multidisciplinary research activity has resulted from a unique global approach driven by industrially relevant concerns and targets. In this prospect, the stimulating role of the Dutch Polymer Institute (DPI) must be pointed out.

The unique contribution of organic and supramolecular chemists to self-assembled/organized materials with functionality at the nanometre length scale is impressive. Smart materials, e.g. endowed with stimulation responsiveness and molecular recognition, illustrate how original and relevant this strategy is and also results in highly outstanding publication and citation record. Top groups competing with the best worldwide laboratories are involved in the TU/e Institute of Complex Molecular Systems, whereas some activity is also running in Twente.

Polymers endowed with biofunctionality are the third route of development conducted with a high international visibility. In addition to the aforementioned supramolecular chemists, biomaterials oriented polymer chemists are key players in this mission. In this respect, the

contribution of Twente to biomaterials and tissue engineering must be emphasized and its embedding in the large institute for Biomedical Technology and Technical Medicine as well. The interdisciplinarity between polymer science and life sciences is rapidly growing and is a challenge clearly identified by the Dutch researchers.

The above mentioned general considerations / conclusions are also valid as far as the role of (heterogeneous) catalysis in chemical engineering is considered. Many aspects of 'classical' catalysis, *viz.* understanding and design at the molecular level of solid and soluble catalysts, and of many aspects concerning design and engineering of catalytic reactors, have been recognized by all peers to be of very high degree of innovation and quality. Whereas this is true for the Dutch Catalysis in general, particularly the work at the three institutes under consideration has been very innovative and outstanding indeed. During the evaluation period under consideration, this broad innovative approach to traditional catalysis connected with a high qualitative as well as quantitative output, remained visible. Moreover, the new approaches / items in studies on catalysis, related to energy, fuel and chemicals production from renewable carbon sources and other 'green sources', aspects of re-engineering, and new approaches to photo- and electrocatalysis, all appear in the new projects of the three institutes. It also seems that at least at two institutes, successful and smooth substitution of retiring group leaders has been possible.

Nonetheless, the Chemical Engineering discipline faces a number of problems. First of all, the number of students in chemical engineering has somewhat stabilized but continues to be low, although this is not a typically Dutch problem. 3TU tries to counter this with some success by attracting students from abroad. In particular in the PhD and postdoctoral positions, a substantial number of non-Dutch researchers can be found. This, facilitated by European exchange programmes, underlines the strength and attraction of the research facilities and programmes at these universities.

Another concern is the change in perspective of the chemical industry in relation to their 'corporate' research. Again, this is not a typically Dutch problem but it has important consequence for the Dutch technical universities, because they have a long tradition in recruiting professors from an excellent 'industrial' pool. This pool is now rapidly drying up and forces the universities to adjust their ways of recruiting. The number of new appointments of researchers with industrial experience is thus expected to decrease. This change in perspective also led to a stronger outsourcing of industrial research to universities, where it is often stimulated through top-down government-sponsored programmes with mixed university-industry participation. Since in most cases matching is expected, a substantial part of the first money stream of the departments is used to support industry driven research, which leaves less, and according to some of the group leaders not enough, money for self determined innovation-driven research. For this, a subtle balance must be found, and the different universities attempt to do so within their specific and different operational models.

The Engineering departments face yet another challenge. The increasing scientific importance and potential applicability of small-scale operations, such as micro-fluidics, nanochemistry or nanobiotechnology, is not yet the way chemical industry at large operates where major processes were developed and continue to be improved with classical approaches and techniques. This duality is, in terms of education and research, sometimes difficult to maintain. Some of the research groups have strongly reorganized and fully opted for this new trend or they have tried to combine both approaches, but with a potential loss of coherence, whereas oth-

ers have kept to 'traditional' topics and have shifted their emphasis in research only to a small extent. The collaboration between the three universities in the 3TU federation might provide an answer to this. A first initiative focused on Sustainable Energy appears to bridge research interests from both the traditional and the 'nano' side together in a constructive manner. In the future, other initiatives could certainly help to maintain the excellent reputation of classical chemical engineering and the world's leading position in bottom-up nano chemistry, as found in the top ranking supramolecular chemistry programmes in Twente and Eindhoven. The recently established Institute for Complex Molecular Systems (ICMS) might be such an approach.

Since the walls between chemistry and other disciplines, such as materials physics, biochemistry and biology, have been substantially lowered, the importance of a multidisciplinary approach has increased enormously. The operational model chosen by Twente University (matrix structure) is one that stimulates these interdisciplinary interactions strongly. Alternatives, such as clusters or interdepartmental programmes, are potentially viable as well.

# ASSESSMENT PER INSTITUTE AND PER PROGRAMME

# 3. Faculty of Applied Sciences - TU Delft

## 3.1. Department of Biotechnology, TU Delft

**Introduction**
The Department of Biotechnology focuses on the multidisciplinary fields of Biocatalysis, Metabolic Engineering, Fermentation Technology, Downstream Processing and Environmental Biotechnology. The Department's activities cover new developments in the Life Science & Technology fields of Analytical Biotechnology, Functional Genomics and Systems Biology. In addition, the Department of Biotechnology engages in education and research on ethical, social and societal issues of (industrial) biotechnology, including public communication.

The Department is organised in seven complementary, interacting programmes:

- ABT: Analytical BioTechnology
- BOC: Biocatalysis and Organic Chemistry
- BPE: Bioprocess Engineering
- EBT: Environmental Biotechnology
- ENZ: Enzymology
- IMB: Industrial Microbiology
- CFT: Complex Fluid Theory (this programme will not be reviewed in this assessment).

**Leadership**
The Department of Biotechnology, one of the six Departments of the Faculty of Applied Sciences, consists of seven research programmes as well as the Botanical Garden and a Working Group on Biotechnology and Society. The latter two are not included in this assessment since they do not represent working groups that participate in chemistry-oriented research activities.

The Department is led by the Department Board, chaired by the head of the Department (Prof. Han de Winde). The Board meets each month and takes strategic decisions concerning research, education and organisation and determines the policy of the Department. Twice yearly strategic meetings are held in order to discuss the developments in research and education. The research programmes are led by programme leaders (full professors).

For the internal processes the Management team (MT-BT) is responsible for the daily management. Furthermore a Project Office is in place to support the scientific staff with financial and project management (e.g. of large consortia, programmes and projects that are coordinated by the Department). In addition to the management several internal advisory bodies are in place.

**Mission & Goals**
The mission of the Department of Biotechnology is to maintain and strengthen its (inter) national leading position in research and education in the field of industrial and environmental biotechnology, by providing an excellent knowledge base for innovation and application of microbial cells and their components. To this end, research performed within the Department of Biotechnology has a strong focus on both fundamental and applied aspects of living microorganisms. It addresses the need for the design of new and sustainable processes and products based on the integration of fundamental knowledge and understanding of both biosciences and process engineering. Research is performed in intensive collaboration with national and

international research groups and with strong links to industry, and contributes to a sustainable future.

**Strategy & Policy**
The Department of Biotechnology is internationally leading in the multidisciplinary fields of bioprocess integration, quantitative physiology and systems biology, metabolic modelling and engineering, synthetic biology, biofilms and biocatalysis. The research of the Department is organised in seven complementary and highly interacting programmes. During the period of review (2001-2007) the Department has experienced an intensive growth in terms of people, scientific scope and organizational structure. The self-evaluation highlights a number of major developments.

The strength of the Department of Biotechnology lies in the carefully built combination of various expertises and disciplines in the field of Biotechnology, ranging from microbiology and molecular genetics, via biochemistry, bioanalytics, enzymology and biocatalysis, to process engineering and downstream processing. This multidisciplinary knowledge base has been built partly through the establishment of the Delft Research Centre for Life Science and Technology (DRC-LST) in 2003. This centre has enabled the Department to attract highly qualified young scientists and to stimulate interdisciplinary research.

The Board of the Department has decided that after the before mentioned period of rapid growth, developments will now be directed towards consolidation. This is intended to ensure the Department's national and international status in Industrial and Environmental Biotechnology and at the same time maintain its strength as a true multidisciplinary Department.

**Evaluative remarks about Leadership, Mission & Goals and Strategy & Policy**
Delft has traditionally had a very strong position worldwide in the biosciences. This started with the nomination of Beijerinck in 1895 as the first Professor of Microbiology in the Netherlands, based on his earlier work at the Gist- en Spiritusfabriek, also in Delft. The relationship between the TU (then the Polytechnical Highschool Delft) and the evolving Gist- en Spiritusfabriek (today part of DSM, via a fusion of Koninklijke Gist-brocades and DSM, and the ultimate absorption of Gb by DSM) continues to this day, with Gb an important source of professorial nominees in microbiology and chemical technology, and the TUD a source of senior R&D staff to the company (Kossen, Roels, Heijnen in the past few decades). There have been strong collaborations between the two Delft organizations, with a very active policy on the part of professors at TH/TU Delft in interacting with the Gist- en Spiritusfabriek in its changing guises. The TU Delft strategy has always included and continues to include a strong commitment to these practical and industrial applications of microbiological insights, and the (bio)technological processes based on these, with activities having continued via the work of Profs. Sheldon, Kuenen, Heijnen and Van Wielen. In order to remain at the leading edge of new developments and to take advantage of the eventual potential of nanobiotechnology, a department at the interface between nanoscience and biotechnology is being set up.

**Resources**
To acknowledge excellent scientists, internal associate professors can be nominated and promoted to full professor by the Dean, in the build-up phase of their career. Attracting young talented researchers is done by stimulating them to apply for NWO grants as well as EU-ERC grants in order to enable them to create their own research lines. Excellent PhD students are stimulated to apply for a Rubicon subsidy in order to obtain international experience.

Table 3.1. provides an overview of the Department's research staff at Institutional level, while table 3.2. provides an overview of the research staff at programme level. In addition to the research staff the Department employs approximately 25 fte technical support staff. These specialised technicians operate and maintain the equipment and are therefore essential in the support of all research projects and the supervision of the education and practical's.

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** |
|---|---|---|---|---|---|---|---|
| Tenured staff | 10,5 | 11,7 | 11,0 | 11,5 | 12,7 | 15,5 | 15,1 |
| Non-tenured staff | 26,5 | 23,5 | 25,3 | 21,9 | 20,3 | 25,0 | 31,0 |
| PhD students | 29,5 | 36,5 | 41,4 | 46,5 | 44,4 | 42,9 | 43,9 |
| **Total research staff** | **66,4** | **71,6** | **77,7** | **79,9** | **77,3** | **83,4** | **90,0** |

Table 3.1. Staff at department level (in research fte)

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** |
|---|---|---|---|---|---|---|---|
| **ABT** | *7,4* | *7,4* | *3,1* | *1,3* | *1,1* | *2,9* | *4,0* |
| Total tenured staff | 1,0 | 0,8 | 0,6 | 0,6 | 0,3 | 0,97 | 1,0 |
| Other non-tenured staff | 2,5 | 2,3 | 2,1 | 0,7 | 0,7 | 1,92 | 2,5 |
| PhD students | 4,0 | 4,3 | 0,4 | - | - | - | 0,5 |
| | | | | | | | |
| **BOC** | *19,9* | *19,4* | *19,9* | *19,3* | *17,9* | *17,8* | *19,7* |
| Total tenured staff | 2,0 | 2,0 | 2,0 | 2,0 | 2,6 | 2,5 | 2,1 |
| Other non-tenured staff | 9,6 | 7,8 | 9,5 | 6,7 | 6,5 | 8,0 | 10,8 |
| PhD students | 8,3 | 9,6 | 8,4 | 10,6 | 8,9 | 6,8 | 6,8 |
| | | | | | | | |
| **BPE** | *14,1* | *15,5* | *15,8* | *17,5* | *18,7* | *20,8* | *23,6* |
| Total tenured staff | 3,3 | 3,6 | 4,2 | 4,2 | 4,1 | 4,6 | 4,4 |
| Other non-tenured staff | 3,2 | 3,1 | 1,3 | 0,5 | 1,5 | 2,8 | 5,2 |
| PhD students | 7,6 | 8,9 | 10,3 | 12,8 | 13,1 | 13,4 | 14,1 |
| | | | | | | | |
| **EBT** | *10,4* | *11,9* | *16,9* | *18,8* | *16,0* | *17,0* | *18,8* |
| Total tenured staff | 1,0 | 1,2 | 1,3 | 1,8 | 1,8 | 2,1 | 2,1 |
| Other non-tenured staff | 5,2 | 5,5 | 6,4 | 6,9 | 4,5 | 4,3 | 5,6 |
| PhD students | 4,2 | 5,2 | 9,2 | 10,1 | 9,8 | 10,6 | 11,1 |
| | | | | | | | |
| **ENZ** | *6,1* | *8,2* | *11,7* | *13,2* | *11,8* | *9,5* | *8,3* |
| Total tenured staff | 1,5 | 1,5 | 1,5 | 1,5 | 1,5 | 1,5 | 1,9 |
| Other non-tenured staff | 2,3 | 2,6 | 2,7 | 3,4 | 4,0 | 4,3 | 3,4 |
| PhD students | 2,3 | 4,1 | 7,5 | 8,3 | 6,3 | 3,6 | 3,0 |
| | | | | | | | |
| **IMB** | *8,4* | *9,1* | *10,3* | *9,9* | *11,8* | *16,0* | *15,6* |
| Total tenured staff | 1,7 | 2,6 | 1,4 | 1,4 | 2,4 | 3,8 | 3,6 |
| Other non-tenured staff | 3,7 | 2,2 | 3,3 | 3,7 | 3,1 | 3,6 | 3,6 |
| PhD students | 3,0 | 4,4 | 5,6 | 4,8 | 6,4 | 8,6 | 8,4 |
| | | | | | | | |

Table 3.2. Staff at programme level (in research fte)

**Funding Policies and Facilities**
Table 3.3. provides an overview of the funding resources and expenditure at institutional level.

| | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % |
| **Funding** | | | | | | | | | | | | |
| Direct Funding | 5,7 | 59 | 5,8 | 52 | 6,3 | 47 | 7,2 | 53 | 8,4 | 51 | 8 | 52 |
| Research Funds | 1,5 | 15 | 1,3 | 12 | 1,4 | 10 | 1,1 | 8 | 1 | 6 | 1 | 6 |
| Contracts | 1,6 | 16 | 2,8 | 25 | 5,2 | 39 | 4,5 | 33 | 6 | 37 | 5,7 | 37 |
| Other | 0,9 | 9 | 1,2 | 11 | 0,6 | 4 | 0,9 | 7 | 1 | 6 | 0,7 | 5 |
| *Total funding* | **9,7** | **100** | **11,1** | **100** | **13,5** | **100** | **13,7** | **100** | **16,4** | **100** | **15,4** | **100** |
| **Expenditure** | | | | | | | | | | | | |
| Personnel Costs | 7,4 | 73 | 8,5 | 79 | 8,5 | 63 | 8,5 | 66 | 9,2 | 64 | 10,4 | 70 |
| Other costs | 2,8 | 27 | 2,3 | 21 | 5 | 37 | 4,3 | 34 | 5,1 | 36 | 4,4 | 30 |
| *Total expenditures* | **10,2** | **100** | **10,8** | **100** | **13,5** | **100** | **12,8** | **100** | **14,3** | **100** | **14,8** | **100** |

Table 3.3. Funding and expenditure of the Department of Biotechnology at institutional level

**Evaluative remarks about Resources, Funding Policies and Facilities**
Delft Chemical technology in its broadest form has developed in just a few locations in Delft, around the Botanical Gardens and the adjacent buildings. The Julianalaan building has gone through repeated adaptations and rebuilding as biotechnology developed and grew, and technical resources and facilities have generally remained suitable for its many purposes. Increased efficiency will soon be achieved in new premises in the emerging Delft Biopolis.

Funding policies are similar to those pursued at other Dutch and European universities. The first funding stream is used to maintain a core staff of highly qualified professors and senior staff, as well as basic research labs and infrastructure. This basis is used to develop a variety of large scale programmes (B-Basic; Kluyver Institute) to initiate and fund major new co-operations, intra- and inter departmentally and among various universities, to pursue new research goals and developments. The impending development of a new department of nanobioscience will be a further boost to this department and the other two departments;

Funding at the level of individual professors and groups continues, of course. There is some debate as to the present and desired balance between large scale programmes and smaller scale projects. The role of fund matching in decreasing the availability of the first money stream for smaller innovative projects is a concern expressed by some.

**Academic Reputation**
Quality assessment and mid-term reviews of research and education form an integral part of the quality control system of the TU Delft, of the Department and of the large programmes in which the Department participates. In addition to the assessment by an international Committee every six years, a three yearly mid-term review is conducted by a national Committee of independent experts. Through several previous peer reviews the Academic Reputation is frequently assessed.

Table 3.4. provides an overview of the CWTS Bibliometric Study between 1997-2006:

| Period | P | CPPex | JCSm | FCSm | CPP/ JCSm | sign. | CPP/ FCSm | sign | JCSm/ FCSm |
|---|---|---|---|---|---|---|---|---|---|
| 1997-2006 | 1.285 | 15,03 | 10,84 | 9,52 | 1,39 | + | 1,58 | + | 1,14 |

**Evaluative remarks about Academic Reputation**
Delft has historically nominated professors who have grown to great heights and have generated famous students in their chosen fields. In the first half of the 20th century the trio Beijerinck, Van Iterson and Kluyver laid the basis for chemical technology and microbiology/botany in Delft, with Van Niel, one of Kluyver's PhD students, who left for the US to spend a lifetime at the Hopkins Marine Station (Stanford) and taught several generations of microbiologists, as probably the most lauded Delft offspring. More recently, Kuenen, Kossen, Roels and Sheldon, who have now retired, played similar prominent roles in microbiology, bioprocess technology, and biochemistry, fields which in Delft have all gradually merged into bio- and chemical technology in the past three decades. Today, a group of young professors and their co-workers are extending this tradition of excellence at Delft. The bibliometric indicators show an overall score above world average.

**Societal Relevance**
The Department of Biotechnology has organised several activities to involve the general public in discussions regarding Biotechnology. These activities include 'Open Days', DNA-labs with which they travel along high-schools in The Netherlands, and the school competition 'Imagine' inviting life scientists to submit proposals for a specific useful and affordable technology in a developing country.

**Evaluative remarks about Societal Relevance**
Several forms of Societal Relevance can be distinguished. One form involves research and teaching that contributes to new applications in industry; either directly via collaborations with interested companies, or indirectly via more general national or European applications directed programmes. The second form is the classical impact of academic research and teaching on societal developments.

The biotechnologically oriented research and teaching has contributed in both areas. The interactions with Gist-brocades and DSM, as well as many other collaborations have been briefly described above. In addition, Delft has created several companies in the bioprocess technology area in the past two decades. Work on wastewater treatment and other bioremediation projects have contributed to the growing importance of these approaches in the Netherlands. Beyond this, the Delft programme Biotechnology & Society (not in this review) has made significant contributions to the larger debate on societal acceptance of biotechnology and genetic modifications.

**Balance of Strengths & Weaknesses**
In the self-evaluation report a SWOT-analysis is provided with the following main points:

*Strengths*
- Strong multidisciplinarity, collaboration and true partnership between programmes
- Expert knowledge and expertise on all aspects of industrial and environmental biotechnology

- Excellent and unique infrastructure
- Combined presence of top scientific and industrial expertise
- Strong interaction between biosciences, process engineering and design
- Strong interaction with and support from (inter-) national industry
- Strong involvement with relevant BSc and MSc creating a steady stream of highly qualified candidates for PhD positions
- Complementary groups in the areas of physics, chemistry and process engineering located nearby.

*Weaknesses*
- Valorisation performance unevenly balanced
- Underrepresentation in EU-Framework 6 consortia and activities
- Housing of the Department presents increasing 'pressure', in terms of crowdedness, flexibility and maintenance of quality
- The increasingly important discipline of Bioinformatics in not adequately secured.

*Opportunities*
- Current global awareness on the importance of a bio-based society
- TU Delft's decision to invest in a brand new laboratory for the Departments of Biotechnology, BioNanoScience and Chemical Engineering
- The planned establishment of a Delft Biotech Science Park with international outlook
- Strong scientific and technological collaborations with several large international industries
- Near-future establishment of a new Department of BioNanoScience within the same lab building.

*Threats*
- Difficulty to attract sufficient highly qualified professionals for faculty or postdoc/PhD positions
- Increasing bureaucracy for funding, reporting and justification of research, hampering the primary process
- Decreasing basic (direct) funding is in growing conflict with the required 'matching' capacity
- Current total size of the Department is reaching its limit
- Strong multidisciplinarity inherently bears a risk of loss of focus.

**Evaluative remarks about the SWOT-analysis**
Developments during the review period have been positive. The SWOT analysis focuses on significant accomplishments. The concerns are modest, and several can equally be seen as the typical accompaniment of success, such as the time necessary to apply for grants, to develop and manage programmes, and so on. As a result the strengths and opportunities clearly outweigh the weaknesses and threats. The most obvious threat appears to be the decreasing availability of top personnel and students, which is addressed through active recruiting in and outside the Netherlands.

### 3.2. Assessment per programme - Department of Biotechnology, TU Delft

The Committee assessed the following programmes of the Department of Biotechnology at the TU Delft:

| | Quality | Productivity | Relevance | Viability |
|---|---|---|---|---|
| **Programmes** | | | | |
| TUD1: Analytical Biotechnology (ABT) | NA | NA | NA | NA |
| TUD2: Biocatalysis & Organic Chemistry (BOC) | 5 | 4 | 5 | 5 |
| TUD3: Bioprocess Engineering (BPE) | 4 | 4 | 5 | 5 |
| TUD4: Environmental Biotechnology (EBT) | 5 | 4 | 5 | 5 |
| TUD5: Enzymology (ENZ) | 3 | 3 | 4 | 3 |
| TUD6: Industrial Microbiology (IMB) | 5 | 4 | 5 | 4 |

The detailed assessment per section follows in the next part of this report.
(NA = not applicable; for details see text.)

**Analytical Biotechnology (ABT)**

| | | |
|---|---|---|
| Programme code: | TUD 1 | |
| Programme director: | Prof. dr. Peter D.E.M. Verhaert | |
| Research staff 2007: | 4,02 fte | |
| Assessments: | Quality: | NA |
| | Productivity: | NA |
| | Relevance: | NA |
| | Viability: | NA |

*Short description*
The section focuses on three themes within the general discipline of Analytical Biotechnology: Miniaturization (towards single cell analysis), 'peptidomics' technology development for applications in bio(techno)logy research, and 'mass spectrometry imaging'.

The mission of the programme is to improve modern protein/peptide mass spectrometry technologies and apply these in modern biology research. Special attention goes to implementing these within the vast microbiology knowhow of the Department, in order to enable highly sensitive and specific analysis of (inter) cellular biological signal peptides. Ideally this introduction of state-of-the-art peptidomics technologies is integrated with the historic interest and expertise of ABT in miniaturization (towards single cell analysis).

*Quality*
On the basis of the publications of the newly appointed director for this programme, the Committee concludes that the necessary expertise is clearly present. The director, who has operated most of the time in an industrial environment, has written a number of relevant publications. They consider the proposed strategy of the project to be relevant and innovative, though some elements seem less relevant at this stage. The bibliometric analysis, as reported in the self-study, for the major part does not refer to the work of the newly appointed director.

*Productivity*
The appointment of the director in the second half of the evaluation period, his high teaching load together with the absence of the required infrastructure, makes it difficult for the Committee to judge on the productivity of the unit. At this stage, the group seems to be built around a small number of PhD students. Nevertheless, the director has been able to publish a sufficient number of publications which were well cited by the scientific community.

*Relevance*
The publications produced outside the frame of the project are relevant for it. The Committee supports the strategy aimed at acquiring/developing three complementary systems for application of peptidomics to problems in biology.

*Viability*
It appears that the necessary infrastructure for carrying out the programme will become available in the very near future. Given the intense contact with the master students in the educational programmes, it is expected that the programme will attract an increasing number of PhD students. Nevertheless, structural efforts should be made to provide the director with help in performing his educational and research tasks, to avoid prolonging the start-up phase.

The director should define a balance between fundamental research and service-type activities, and be aware of the risk of developing a mere analysis line.

**Conclusions**
The director of this (new and rather small) group was appointed at the end of the evaluation procedure and the bibliometric data largely pertain to his predecessor. After his appointment to the present position, the director has had a rather high teaching load, while the necessary infrastructure needed for the programme had to be acquired. Nevertheless, the Committee fully agrees with the strategy of the department in this area. The proposed approach and methodology look promising. The necessary expertise of the director is adequate for successfully starting up this programme. It is recommended that the teaching load of the director be reduced, and that the emphasis comes to lie on the development of a new research line. One should be aware of the risk of being trapped in the development of a mere analysis line for the exclusive support of other programmes.

**Biocatalysis and Organic Chemistry (BOC)**

| | | |
|---|---|---|
| Programme code: | TUD 2 | |
| Programme director: | Prof. dr. Roger A. Sheldon (until July 2007) and Prof. dr. Isabel W.C.E. Arends | |
| Research staff 2007: | 19,68 fte | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The BOC section operates from a core competence in organic chemistry, and catalysis in particular. Both chemocatalytic (metal and organic based) as well as biocatalytic methodologies are studied. Over the years focus has shifted towards biocatalysis, and the expression, mutation and screening of enzymes are now included in the section's research capabilities.

The mission of the programme is directed towards the design of atom-efficient, low waste processes for the synthesis of high-added-value chemicals, such as pharmaceuticals and chiral intermediates. The programme designs and studies the development of human-tissue binding metal complexes in the framework of bio-imaging.

The research is organized into four closely interacting themes:

- Theme 1: Development of novel oxidation and reduction catalytic protocols
- Theme 2: (Bio)catalytic cascades towards synthesis of chiral and highly added value molecules
- Theme 3: Development of enzyme design strategies
- Theme 4: Bio-imaging

*Quality*
In the review period, the Biocatalysis and Organic Chemistry group has been covering the gap between chemo- and biocatalysis. Worldwide, it has been one of the few groups with this unique approach. Although covering a wide variety of topics, the approach remained very well focussed indeed. Publications were of very high quality, as is evident after normalization for differences in publication policy among different research fields (CPP/FCSm ratio is very high), and were very well cited by their peers. The director and the other staff members are highly visible researchers both in the chemo- and in the biocatalytic area. The overall quality of the research is internationally at the forefront, with a very significant impact in the field. The group has achieved an international top-status.

*Productivity*
A high number of publications have appeared in the better journals of the discipline. The Committee feels that a supplementary effort is still possible to further increase the number of PhD's. The number of cited papers per full-time equivalent staff is very good. Papers similarly cover many aspects of the very broad area studied.

*Relevance*
The group makes very significant efforts to implement their knowledge via a very active patent policy. The valorisation of knowledge is made via interaction with preferred industrial partners, including own spin-off initiatives.

*Viability*
The review period covers the time preceding the retirement of Prof. Sheldon. The Committee feels that succession has occurred smoothly. While the size of the group is being maintained, the shift towards new enzyme-related topics using advanced techniques is significant, though the bridge with chemo-catalysis remains in position. The actualisation of the scientific topics was done with much inventiveness and creativity.

**Conclusion**
The Biocatalysis and Organic Chemistry group used to be one of the few TOP-groups trying to connect chemo- and biocatalysis. The output quality in the past evaluation period has been excellent, while the Committee expects a continued effort to further increase the number of dedicated PhD students. The Committee feels that a smooth transition after the retirement of Prof. Sheldon has taken place. The group size remains adequate and the expertise is present to perform with success the high level and creative research presented.

**Bioprocess Engineering (BPE)**

| | | |
|---|---|---|
| Programme code: | TUD 3 | |
| Programme director: | Prof. dr. ir. J.J. Heijnen and Prof. dr. ir. L.A.M. van der Wielen | |
| Research staff 2007: | 23,62 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
This programme focuses on the scientific and technological aspects of biobased conversion and separation processes aimed at chemicals, pharmaceuticals, fuels and bio-energy. In the period under review the programme dealt with three industrially relevant organisms and with chromatography, crystallisation, particle formation, process design in four themes.

The mission of the programme is to develop novel concepts for compact, clean and efficient manufacturing processes for the production of chemicals, pharmaceuticals, fuels and bio-energy. The programme includes projects to implement and improve the performance of new enzymatic pathways, both *in vitro* (with isolated enzymes) or *in vivo* (using whole cell systems based on bacteria and yeasts). Special attention is given to design methodology and bioprocess integration.

*Quality*
The contributions of the Delft Bioprocess Engineering group follow a long line of Delft achievements in process engineering, often in close association with industry. The leadership of the programme is in very good hands with Profs. Heijnen and Van Wielen, each with a specific but necessary imprint on the programme. The scientific impact of the publications of the laboratory is very good and could probably be improved even further with slightly more focus on high impact journals in the field.

*Productivity*
The number of PhD theses is perhaps somewhat lower than might be expected of the laboratory, given the number of senior staff. At the same time, the laboratory is deeply involved in the teaching of process development engineers, a programme much appreciated by industry. The extra teaching load is significant, which may reduce the number of PhD graduates produced per year.

*Relevance*
Bioprocess technology continues to be extremely relevant to industry, with additional direct and indirect societal impact. Delft has traditionally played the major role in this area in the Netherlands, and continues to do so today.

*Viability*
With a history of well over 100 years, there is absolutely no doubt about the long-term viability of the bioprocess activities in Delft and in this programme.

**Conclusion**

The Delft Bioprocess Engineering laboratory as now constituted is well positioned, staffed and equipped to face the next decades with confidence. There are not many laboratories worldwide working on similar problems that can equal the performance of the Delft Bioprocess Engineering laboratory. If improvements are to be pursued, this might be done via focused publication in highest impact journals and by a moderate increase in the number of yearly PhD graduates.

**Environmental Biotechnology (EBT)**

| | | |
|---|---|---|
| Programme code: | TUD 4 | |
| Programme director: | Prof. dr. ir. M.C.M. van Loosdrecht | |
| Research staff 2007: | 18,81 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The research programme focuses on microbiology and biotechnology of conversions by mixed microbial cultures in engineered systems.

The mission of the programme is to master microbial mixed cultures by understanding the behaviour of complex microbial mixed cultures and microbial ecosystems and the use of that knowledge in developing novel concepts for application of such ecosystems in (waste)water treatment processes, and in the production of chemicals and other applications. The programme focuses on Biofilm Processes, Molecular Ecology, Conversion of Inorganic Compounds and Metabolic Based Modelling

The overall aim of the programme is to understand the behaviour of microbial ecosystems, and integrate these in processes for waste treatment and valorisation. The work can be divided into three main themes and into a portfolio of process technology projects reaching across the theme boundaries. The more basic research lines are integrated in process technology oriented projects. The research themes are:

- Theme 1: Microbiology and Molecular Ecology
- Theme 2: Biofilm Processes
- Theme 3: Metabolic Flux Modelling of mixed cultures.

*Quality*
All parameters from the bibliometric study referring to quality of the research output point to a very significant contribution to the field, in terms of quality of the publications, originality of the approach and coherence of the individual topics. The combination of physiological and chemical-technological aspects with the principles of inorganic bioconversions is unique. The competence of the senior staff of the group is broad, overlapping and adequate to an effective solution of the problems tackled. According to the bibliometric scores the group is leading in the broad area of research involved. The highly interdisciplinary approach to the problems is worth mentioning explicitly.

*Productivity*
The quantified productivity is very good, although an increased effort in attracting excellent PhD students is advisable. On the other hand, the output per invested full-time research equivalent is of an excellent level. The output normalized for field is very good.

*Relevance*
Several of the major research topics are problem- and industry-driven, although the output is balanced between industrial implementation and publication in highly-cited scientific journals. A number of patents describe valorisation attempts, while the creation of two spin-off companies, aims at specific valorisation. The development of a biodesulfurisation technology is an example of successful implementation of own research results.

*Viability*
The research approach, with a selection of research topics, and overlapping of a broad spectrum of competences among the senior researchers, seems to be an ideal environment for research leading to applications as well as to fundamental understanding in a creative and innovative way,. According to the staff, there is a discrepancy between the abundant availability of large projects and the number of high quality researchers that can carry out such projects. In the view of the Committee, the funding agencies should give special attention to sponsoring small projects of a highly innovative nature.

**Conclusion**
The Environmental Biotechnology Group shows an excellent output in terms of high quality contributions in an area where physiological and chemical aspects of mixed cultures are combined. Although industry-driven, the output is of excellent scientific quality. The Committee feels that an increased number of high-quality PhD students could improve the output even more. The Committee also feels that the group would benefit from the presence of a sponsored framework for small very innovative projects. There is a good balance between industrial valorisation and development of new fundamental concepts.

**Enzymology (ENZ)**

| | | |
|---|---|---|
| Programme code: | TUD 5 | |
| Programme director: | Prof. dr. W.R. Hagen and Prof. dr. S. de Vries | |
| Research staff 2007: | 8,29 | |
| Assessments: | Quality: | 3 |
| | Productivity: | 3 |
| | Relevance: | 4 |
| | Viability: | 3 |

*Short description*
The research programme performs multidisciplinary research in fundamental and applied enzymology with footholds in the mono-disciplines of (molecular) biology, (transition ion) (bio)chemistry and (magnetomolecular) physics. The mission is to study the fundamental and practical aspects of metalloenzyme structure and function with emphasis on the roles of transition ions in biocatalysis. The programme includes work on cellular physiology, and methodology development. The programme is divided into two main research themes:

- Structural aspects of biocatalysis. These are examined using metalloproteomics, via studies of metalloprotein magnetic properties, and by studying the biosynthesis of cofactors.
- Functional aspects of biocatalysis. These are studied by examining the pre-steady-state kinetics of metalloenzymes.

*Quality*
The leadership of the programme by Profs. Hagen and De Vries, their scientific approach and contributions to the field, including a recent monograph on EPR methodology as applied to metalloenzymes, have been good**.** The scientific impact of the publications might be improved, possibly via more focus on high impact journals in the field.

*Productivity*
Where scientific contributions are concerned the quantity is good. However, the number of PhD theses is lower than might be expected, given the number of senior staff.

*Relevance*
The contribution of EPR studies to the understanding of the structure and function of metalloenzymes has been very good. How EPR methods and their importance will develop in the future remains to be seen, since there are useful alternatives.

*Viability*
Alternatives to EPR methods will ultimately reduce the contribution of EPR approaches to studies of the mechanism of action of metalloenzymes. At that point the laboratory will have to face important choices between developing new approaches or seeing eventually its impact decrease further.

**Conclusion**
The laboratory has made significant contributions to the understanding of metalloenzyme catalysis and cofactor metabolism in the past. It has expertise in a number of methodologies of importance in enzymology but as alternative methodologies emerge,

the laboratory might have to face important choices with respect to its directions and methodologies.

**Industrial Microbiology**

| | | |
|---|---|---|
| Programme code: | TUD 6 | |
| Programme director: | Prof. dr. J.T. Pronk | |
| Research staff 2007: | 15,55 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The research programme operates from a core competence in quantitative physiology of industrial microorganisms, complemented with molecular and systems biology approaches. In an applied sense, IMB is active in the fields of metabolic engineering/synthetic biology and evolutionary engineering. During the period under review, the programme has focused on two microorganisms in particular.

The mission of the research programme is to quantitatively and integrally understand the interaction of industrial microorganisms and their genomes with their industrial environments, thereby enabling rational design and optimization of microbial strains and fermentation processes.

The research is organized in three complementary and interacting themes:

- Theme 1: Quantitative Physiology/Experimental Systems Biology
- Theme 2: Molecular Biology of Industrial Microorganisms
- Theme 3: Metabolic and Evolutionary Engineering

*Quality*
The leadership of the programme is excellent and in fine hands with Prof. Pronk, who has surrounded himself with a strong group of young colleagues and co-workers.

*Productivity*
The number of publications has been very good but could be increased and targeted to higher impact journals. The number of PhD theses has been lower than might be expected for the laboratory, given the number of senior staff. This might, at least in part, be due to the relatively short period of development of the new laboratory in the post-Kuenen era.

*Relevance*
By definition, industrial microbiology is extremely relevant to industry, and in Delft this remains as true as it has been in the past.

*Viability*
The long-term viability of industrial microbiology in Delft remains as strong as it has been in the past. For the time being however the laboratory is in the process of fully establishing very ambitious and highly industry-dependent research programmes, the viability of which, and hence that of the laboratory in its planned state, do not yet merit the top score.

**Conclusion**

Industrial Microbiology in Delft has a long and very fruitful history, both academically, and in its relationships and collaborations with industry. Following the illustrious predecessors from Beijerinck to Kuenen, Prof. Pronk has taken important steps to position the Delft laboratory at the forefront of modern molecular and applied microbiology. Further small but important improvements of productivity and viability will depend on increasing publication impact and the stability of the financial support structure.

## 3.3. Department of Chemical Engineering, TU Delft

**Introduction**
The research of the Department of Chemical Engineering (DelftChemTech) covers the full area of nanochemical engineering, from design, synthesis and fundamental studies of molecules as building blocks of nano-sized structures and subsequently of tailor-made products for application and studies in the areas of energy and health, including process technology aspects of controlled scale-up.

The department builds upon its proven strength in chemical engineering and develops the science and technology of functional nanostructured systems, from molecules to the design of products and processes.

The Department's research has a strong focus on Nanochemical Engineering. The research activities involve studies on functional nanosystems, from the design and synthesis of molecules to the process technology aspects of mass-production. The Department consists of seven research groups and participates in several TU Delft, interuniversity, national and European collaborative research bodies.

From the seven discipline related programmes of the Department six are included in this review. The seventh programme, Materials for Energy Conversions and Storage (MECS), is only very recently established and will therefore not be included in this evaluation. Each programme is headed by a full professor.

The programmes that are evaluated are:

- CE: Catalysis Engineering
- NSM: NanoStructured Materials
- NOC: Nano-Organic Chemistry
- OM: Opto-electronic Materials
- PPE: Product & Process Engineering
- SAS: Self-Assembling Systems

**Leadership**
The Department is headed by Prof. dr. E.J.R. Sudhölter, who is responsible for the quality and quantity of the personnel input in education and research, for the overall quality of the research and for the departmental budget. The department head leads the Management Team, made up by the programme leaders, a Personnel Officer and the Department Executive Secretary. The department head reports to the Faculty Dean and represents the department in the Faculty Management Team.

**Mission & Goals**
The mission of the Department is to generate knowledge and educate people in the area of nano-chemical engineering to improve the quality of life for a sustainable society, focusing on energy, water, health and environment. Building upon its proven strength in chemical engineering, the department develops the science and technology of functional nanostructured systems, from molecules to the design of products and processes.

**Strategy & Policy**
The research focus on energy, water, health and environment matches with the main themes as defined by the Board of the TU Delft. Energy has been an important subject within the Department for a long time and will remain so in the future. It was projected that chemical engineers play and will continue to play an important role in our modern and technological society in order to fulfil the future demands. Examples are sufficient, clean and renewable energy, water, healthy food, pharmaceutical products, (nano)medicine, electronics, consumer products, materials and biotechnology. The involvement of chemical engineers in these areas represents a considerable challenge to education and research in chemical engineering in the near future.

The department has undergone a major overhaul starting in 2004 in order to meet these challenges. At the moment the department focuses on fundamentals of molecular conversions, on chemical, biological and physical transformations, on multi-scale analysis at varying length- and timescales, on system analysis and system synthesis. A new development within the department concerns the design at the molecular level of products and processes: 'from molecule to products'.

The new direction of the Department does not imply a discontinuation of 'traditional' process technology at the TU Delft. Parts of the expertise have been moved to another Department (Multi-Scale Physics) and to the Faculty of Mechanical, Maritime and Materials Engineering (3mE). The reorientation of the DelftChemTech Department has led to a significant broadening of the chemical engineering scope at TU Delft as a whole.

**Evaluative remarks about Leadership, Mission & Goals and Strategy & Policy**
Both the long-term objectives and the organisational structure of the department, that underwent a major overhaul during the evaluation period 2001-2007, are in line with recommendations of the former assessment Committee. The main focus, which is now placed on nanochemical engineering, is consistent with the emergence of nano-chemistry as a scientific discipline and with a shift in industrial practices that is perhaps to be expected.

The activities of five of the seven sections are typically devoted to nano-chemistry (NOC), nano-materials (NMP), nanoscale molecular optoelectronics (OM) and nano-devices/systems (SAS). As expected in a Chemical Engineering department, a strong emphasis remains on catalysis engineering (CE) and product and process engineering (PPE). In general, the restructuring is well-balanced, making the strategy and policy well-suited to the newly stated scientific and educational mission.

The success will, however, depend on the extent to which the commonly agreed mission will be shared by all staff members. A major role of the leadership will be to integrate the research effort and expertise of each section, to promote and reward multidisciplinarity, to incite the section leaders to innovation and to provide, accordingly, the department with an appealing visibility.

**Resources**
Table 3.5. provides an overview of the research staff at department level. In table 3.6. the research staff for each programme is provided.

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| Tenured staff | 14,3 | 14,2 | 13,5 | 12,5 | 12,2 | 11,3 | 12,3 |
| Non-tenured staff | 19,1 | 21,7 | 25,0 | 22,2 | 18,1 | 22,3 | 26,5 |
| PhD students | 36,4 | 40,0 | 41,5 | 36,9 | 32,9 | 32,3 | 31,6 |
| **Total research staff** | **69,7** | **75,9** | **79,9** | **71,6** | **63,2** | **65,9** | **70,4** |

Table 3.5. Staff at department level (in research fte)

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| **CE** | *28,7* | *29,8* | *31,5* | *28,8* | *27,4* | *24,9* | *23,0* |
| Total tenured staff | 4,8 | 4,5 | 4,4 | 4,0 | 4,6 | 4,5 | 4,2 |
| Other non-tenured staff | 10,7 | 9,8 | 10,9 | 10,3 | 9,9 | 9,6 | 8,5 |
| PhD students | 13,2 | 15,7 | 16,2 | 14,4 | 13,0 | 10,7 | 10,2 |
| **NSM** | *25,4* | *28,9* | *32,5* | *31,5* | *25,2* | *30,2* | *31,1* |
| Total tenured staff | 5,6 | 5,4 | 5,1 | 4,9 | 4,1 | 3,3 | 3,7 |
| Other non-tenured staff | 5,6 | 9,6 | 11,4 | 10,4 | 7,1 | 11,6 | 14,7 |
| PhD students | 14,2 | 14,0 | 16,1 | 16,3 | 13,9 | 15,2 | 12,6 |
| **NOC** | *0,9* | *0,5* | *0,5* | *0,5* | *0,5* | *0,5* | *1,0* |
| Total tenured staff | 0,9 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 1,0 |
| Other non-tenured staff | - | - | - | - | - | - | - |
| PhD students | - | - | - | - | - | - | - |
| **OM** | *11,9* | *13,9* | *13,0* | *9,3* | *9,1* | *9,4* | *10,6* |
| Total tenured staff | 2,5 | 3,3 | 3,0 | 2,7 | 2,5 | 2,5 | 2,5 |
| Other non-tenured staff | 2,8 | 2,4 | 2,7 | 1,5 | 1,2 | 1,1 | 2,4 |
| PhD students | 6,6 | 8,1 | 7,2 | 5,1 | 5,5 | 5,9 | 5,6 |
| **PPE** | - | - | - | - | - | - | - |
| Total tenured staff | - | - | - | - | - | - | - |
| Other non-tenured staff | - | - | - | - | - | - | - |
| PhD students | - | - | - | - | - | - | - |
| **SAS** | *2,8* | *4,0* | *3,6* | *2,5* | *1,7* | *1,5* | *6,9* |
| Total tenured staff | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 0,9 |
| Other non-tenured staff | - | - | - | - | - | - | 0,9 |
| PhD students | 2,3 | 2,3 | 2,0 | 1,1 | 0,5 | 0,4 | 3,1 |

Table 3.6. Staff at programme level (in research fte). No fte data is given for PPE since the staff was not active as such in the programme during the review period.

**Funding policies and Facilities**

Table 3.7. provides an overview of the funding resources and expenditure at institutional level.

| | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % |
| **Funding** | | | | | | | | | | | | |
| Direct Funding | 6,7 | 51 | 8,2 | 57 | 7,7 | 52 | 9,1 | 61 | 8,0 | 58 | 8,6 | 64 |
| Research Funds | 1,8 | 14 | 1,4 | 10 | 1,5 | 10 | 1,2 | 8 | 1,6 | 12 | 1,2 | 9 |
| Contracts | 4,0 | 30 | 4,1 | 29 | 4,7 | 32 | 3,9 | 26 | 3,4 | 25 | 2,9 | 22 |
| Other | 0,7 | 5 | 0,6 | 4 | 0,8 | 6 | 0,7 | 5 | 0,8 | 6 | 0,7 | 5 |
| *Total funding* | **13,2** | **100** | **14,3** | **100** | **14,7** | **100** | **14,9** | **100** | **13,8** | **100** | **13,4** | **100** |
| **Expenditure** | | | | | | | | | | | | |
| Personnel Costs | 11,8 | 77 | 12,0 | 79 | 12,3 | 80 | 11,8 | 79 | 8,6 | 75 | 7,9 | 70 |
| Other costs | 3,5 | 23 | 3,2 | 21 | 3,0 | 20 | 3,1 | 21 | 2,8 | 25 | 3,3 | 30 |
| *Total expenditures* | **15,3** | **100** | **15,2** | **100** | **15,3** | **100** | **14,9** | **100** | **11,4** | **100** | **11,2** | **100** |

Table 3.7. Funding and expenditure of the Department of Biotechnology at institutional level

**Evaluative remarks about Resources, Funding policies and Facilities**

The most important observation is that the budget that was in deficit in 2001, was in equilibrium in 2005 and exhibited a profit margin in 2007. As a rule, the contribution of contracts to the whole budget is decreasing since 2004 (from 32 to 21.6 %), which is mainly compensated by the direct funding (from 52.4 to 64.2%).This evolution is consistent with an increased emphasis on the fundamental aspects of applications. The total staff is the same in 2007 as in 2001, with however intermediate fluctuations. The general trend is an increase in the number of PhD students. Moving to a new housing is a stimulating prospect in terms of infrastructure, which is good anyway, and interactions within the Faculty of Applied Sciences. An increased targeting of potential funding by European programmes should be considered.

**Academic Reputation**

Table 3.8. provides an overview of the CWTS Bibliometric Study between 1997-2006:

| Period | P | CPPex | JCSm | FCSm | CPP/ JCSm | sign. | CPP/ FCSm | sign. | JCSm/ FCSm |
|---|---|---|---|---|---|---|---|---|---|
| 1997-2006 | 1125 | 9,98 | 7,80 | 5,27 | 1,28 | + | 1,89 | + | 1,43 |

**Evaluative remarks about Academic Reputation**

The indicators listed in Table 3.8. are higher than 1.0, particularly the crown indicator (1.89), and the impact of the articles is above world average (+). A publication strategy aiming at quality must be maintained not only for the international visibility to be increased but also at the benefit of education and future of the (PhD) students.

**Societal Relevance**

The mission statement of the Department states that the research is focussed on nanochemical engineering to improve the quality of life for a sustainable society, focussing on energy, water, health and environment.

DelftChemTech has extensive contacts with industrial partners throughout the world, through which valorisation is primarily accomplished. Additionally, in several spin-off companies, technology transfer is stimulated.

**Evaluative remarks about Societal Relevance**
The societal relevance of the research conducted in this department is obvious. The research will ultimately lead to cleaner and more sustainable energy usage for e society, ensure future supplies of clean water, stimulate work towards a clean environment and create a strong basis for applications in the health area.

**Balance of Strengths & Weaknesses**
The self-evaluation report contains a SWOT-analysis with the following main points:

*Strengths*
- Both multidisciplinary partnerships and monodisciplinary collaborations
- A commonly agreed mission in the emerging research field of nanochemical engineering
- Coverage of all expertises from molecule to product level, with a special focus on today's important concerns regarding energy, sustainability and health
- Fresh group of motivated staff
- Strong movement towards integration
- Good infrastructure
- Complementary groups in the areas of physics, biotechnology and engineering located nearby

*Weaknesses*
- Communication between faculty members and non-faculty members is not optimal
- Collaboration between different programmes is not optimal
- The visibility of the renewed Department is still insufficient
- Innovative power of the Department is not optimal

*Opportunities*
- Nano-chemical engineering is a young research area with many opportunities to define a unique and successful research programme
- Wide interest in and funding for the themes of energy, sustainability, water and health
- Strong commitment of Delft University of Technology and fellow Departments to develop the area of nanochemical engineering
- Sufficient vacancies to attract new staff members
- Moving to new housing will stimulate interactions within the faculty

*Threats*
- Difficulty to attract highly qualified people for faculty and PhD/Post-doc positions
- Increased bureaucracy for funding and justification of our research
- Too much emphasis in society on the short-term applicability of results
- Departure of chemical research from industries in The Netherlands and possible departure of these industries as a whole.

**Evaluative remarks about the SWOT-analysis**
The SWOT analysis provides a good snapshot of the framework in which the department not only wants to grow, but will also have to grow. Points of attention should be a better coherence of the programmes as well as an increase of the national and even more the inter-

national visibility of the department. This and an improved interaction between the different programmes and communication between the programme leaders can only be realized with strong leadership.

### 3.4. Assessment per programme: Department of Chemical Engineering, TU Delft

The Committee assessed the following programmes of the Department of Chemical Engineering at the TU Delft:

| | Quality | Productivity | Relevance | Viability |
|---|---|---|---|---|
| **Programmes** | | | | |
| TUD 7: Catalysis Engineering (CE) | 5 | 5 | 5 | 5 |
| TUD 8: Nano-organic Chemistry (NOC) | NA | NA | NA | NA |
| TUD 9: Nanostructured Materials (NSM) | 3 | 4 | 4 | 3 |
| TUD 10: Opto-electronic Materials (OEM) | 4 | 4 | 4 | 5 |
| TUD 11: Products & Process Engineering (PPE) | NA | NA | NA | NA |
| TUD 12: Self-assembling Systems (SAS) | NA | NA | NA | NA |

The detailed assessment per section follows in the next part of this report.
(NA : not applicable)

**Catalysis Engineering (CE)**

| | | |
|---|---|---|
| Programme code: | TUD7 | |
| Programme director: | Prof. dr. J.A. Moulijn | |
| Research staff 2007: | 22,97 fte | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The research in the catalysis engineering programme covers catalyst development to industrial application in (multiphase) chemical reactors and fundamental studies of the working principles of these catalysts. The mission of the programme is to focus on novel concepts for creating optimal environments for catalytic reactions on a multiscale level, from Angstroms to meters, marrying catalysis to engineering. The multi-level approach integrates the molecular scale (micro level), the catalyst and reactor (meso level) up to the product and process level (macro level), leading to a rational design of and precision in catalytic operations.

*Quality*
The Catalysis Engineering group belongs to the top in the field and is very successful in linking (heterogeneous) catalysis with reaction engineering. This original approach requires the simultaneous use of a variety of advanced tools in order to tackle a wide variety of topics. The team has obtained an excellent track record in doing so. Generally, the Committee feels that the output is coherent, very well focussed and stands for a very significant contribution to the field. The past and present director as well as the other permanent staff members are very prominently present in the field. The normalized output is considered to be excellent.

*Productivity*
The publications are found in the top and better journals of the discipline, while the number of publications per full-time equivalent staff is excellent. The number of defended PhD theses is very high.

*Relevance*
The group makes a very significant effort to implement their developed knowledge via patents. Valorisation occurs with the help of preferred industrial partners. The Committee appreciates the combination of excellent fundamental output with industrially implemented knowledge.

*Viability*
The review period covers the directorship of Prof. Moulijn, while the presentation was focussing on the first results under the new staff. Clearly, the 'old' topics have been revitalized, while new highlights have been introduced in a very timely fashion. The study of new promising catalytic materials, viz. metallo-organic frameworks and superacids/superbases, as well as new platform chemicals from biomass and new engineering approaches, have been introduced. The number of researchers in combination with the number of new projects stemming from third party funding, seems to assure a successful continuation of the very relevant combination between heterogeneous catalysis and reaction engineering.

**Conclusion**
The Catalysis Engineering group shows an excellent track record in every aspect of the evaluation criteria. The group has been able to combine current topics from the area of reactor engineering and heterogeneous catalysis in a creative and focussed way. During the transition of the directorship, old topics have been revitalised, while new relevant ones have been introduced. The Committee sees all necessary elements for a future successful continuation of the activity of this group, in particular in keeping a good balance between dissemination and implementation of science.

**Nano-organic Chemistry (NOC)**

| | | |
|---|---|---|
| Programme code: | TUD 8 | |
| Programme director: | Prof. dr. E.J.R. Sudhölter | |
| Research staff 2007: | 0.96 fte | |
| Assessments: | Quality: | NA |
| | Productivity: | NA |
| | Relevance: | NA |
| | Viability: | NA |

*Short description*
The Nano-Organic Chemistry programme covers the synthesis, characterization and self-assembling properties of (bio)organic molecules and macromolecules towards nano-sized architectures.

The mission of the programme is to conduct outstanding scientific research and education in the above-mentioned area. The programme aims to understand the relation between precise molecular structure and conditions (such as temperature, solvent, interface) with the dynamic, thermodynamics, and morphology of the nano-sized architectures formed by self-assembly.

At the start of the NOC programme in 2007, it was decided to concentrate on three research themes:

- Theme 1: NanoCapsules in Medicine (Dr. Wolter Jager)
- Theme 2: Molecular sensing on patterned and nanostructured silicon (Dr. Ir. Louis de Smet)
- Theme 3: Fluorescent Probes and Sensors (Dr. Wolter Jager)

*Quality*
The research activities of this group started in January 2007, which makes any scoring irrelevant. The programme director comes from Wageningen University, where he was in charge of a large research group (5.9 fte) and where he acquired expertise in chemical and physical processes at surfaces. In Delft, his ambition is to build-up a research group of a smaller size (8-10 PhD students) that will be able to make a strong impact on specific issues closely related to the missions of the Chemical Engineering department, i.e. health, energy and water. The three research themes that have been selected are all oriented towards nano-chemistry and nano-devices. Being topical, this line of research will face strong competition, as a result of which originality and innovation will be of a major importance for the scientific and technical output to be of high quality.

*Productivity*
The bibliometric data reported for the three staff members combined is very good, which is very promising for the productivity of this new group.

*Relevance*
The expertise of the staff members in the design and synthesis of (macro)molecules endowed with self-assembling or sensor properties as well as in surface chemistry, is a great asset for making scientifically and technically relevant headway in a very competitive field.

*Viability*
Coherence in the growth of the group and its research effort is a key issue. Involvement in a network of collaborations and research funding organizations is also essential, which is obviously the case for the research conducted in Theme 2.

**Conclusion**
The Committee would recommend this new group to pay attention to innovation and coherence in its research effort, as these will be key elements to achieve strong international visibility and to attain high quality and scientific relevance.

**NanoStructured Materials (NSM)**

| | | |
|---|---|---|
| Programme code: | TUD 9 | |
| Programme director: | Prof. dr. S.J. Picken | |
| Research staff 2007: | 31,08 fte | |
| Assessments: | Quality: | 3 |
| | Productivity: | 4 |
| | Relevance: | 4 |
| | Viability: | 3 |

*Short description*
The NSM programme deals with the fundamental investigation of materials and systems based on complex polymers and (inorganic) particles including their use in energy storage and conversion systems.

The mission of the programme is to investigate the fundamentals and applications of advanced nanostructured polymer and particle-based systems (ranging from their structure, dynamics and properties to their production, characterization and processing) including the use of novel concepts from self-assembly and supramolecular chemistry.

Within the framework of the reorganization of the DelftChemTech Department the sections Polymer Materials and Engineering, Particle Technology and the Li-ion battery activities within Inorganic Chemistry joined forces to form the NSM programme in October 2005.

The research is divided into three primary themes:

- Theme 1: Polymer Materials and Engineering (Prof. dr. S.J. Picken)
- Theme 2: Particle Technology (Prof. dr. A. Schmidt-Ott)
- Theme 3: Energy Conversion and Storage (dr. E. Kelder)

*Quality*
The work in the area of polymer materials and engineering (Theme 1) aims at combining fundamental understanding of structure-property relations with application oriented research and it gets good national recognition, as is, for example, confirmed by substantial and continued funding from the Dutch Polymer Institute. The research on glass transition and physical aging in polymers and composites and that on discotic liquid crystals was published in a number of good to very good journals and made some impact.

Within Theme 2 forefront research in the particle technology area, in the field of physics of granular systems, was carried out and published in the best journals and has had an excellent impact. However, the Theme head and the present members had a particularly modest publication record during the assessment period and their work needs to become visible. The new orientation of the sub-programme towards gas phase synthesis of nanoparticles is a promising step.

The energy conversion and storage team (Theme 3) mainly dealt with synthesis of materials for electrodes for Li-ion batteries, was well integrated in European and national collaborative projects and has a creditable publication record.

*Productivity*
Overall, the productivity of the programme was very good, but the number of PhD theses could be raised. Also, the very small number of papers published by scientists presently involved in theme 2 is of concern.

*Relevance*
The programme is rather diverse, but there is no doubting the relevance on a topic basis. Maintaining and developing fundamental understanding of structure and properties of plastics, composites and nano-composites, fibers or coatings, synthesizing new hybrid organic-inorganic materials is of great importance to traditional and less traditional industries. The programme is useful for educating knowledgeable students and researchers and can in principle implement the application-oriented culture through a well developed network of industrial relations.

*Viability*
In terms of research staff this programme was the largest in the Department. The biggest challenge that the programme faces is to improve both the quality and productivity of the research of the particle technology group by integrating it in a common research projects on hybrid materials. Also of concern are the coherence of the research projects and the large spectrum of materials and topics that the teams deal with. It seems essential that the programme's research becomes more focused and some steps in this direction are already taken. Such a focusing effort is particularly desirable in view of the creation within the Department of new programmes dealing with some similar subjects led by very enthusiastic and gifted scientists.

**Conclusion**
The research carried out in the programme is relevant for industry and education. It has led to some innovative results. The research has a potential to develop further in the area of hybrid materials: polymer -inorganic, polymer-liquid crystals and gel-particle systems, but critical prerequisites are the good integration of various teams under consistent and strong leadership and more coherence and focus.

**Opto-electronic Materials (OM)**

| | | |
|---|---|---|
| Programme code: | TUD 10 | |
| Programme director: | dr. J.M. Warman (until 2003); Prof. dr. L.D.A. Siebbeles (2003 onwards) | |
| Research staff 2007: | 10,6 fte | |
| Assessments: | Quality: | 4 |
| | Productivity: | 4 |
| | Relevance: | 4 |
| | Viability: | 5 |

*Short description*
The research in the programme is performed on charge carriers and excited states in molecular materials with potential applications in optoelectronic devices, nanoscale molecular electronics and nanomedicine.

The mission of the programme is to provide fundamental insights into the factors that govern the nature and dynamics of charge carriers and excited states in optoelectronic materials. In 2003 the decision was made to discontinue research on primary interactions of high-energy radiation. This decision was made in order to focus on the growing (inter)national scientific and technological interest in nanoscale molecular optoelectronics. For this the DelftChemTech Department was a more suitable environment and the Department was joined in 2005.

The research programme focuses on the nature and dynamics of charge carriers and electronic excited states (exitons) in functional materials..

*Quality*
Having built an excellent infrastructure and striving to innovate in terms of unique measurement equipment, the group successfully combines experiments and theory and fulfils its goal to provide fundamental knowledge for design of materials with specific optoelectronic properties. The group collaborates with top scientists, has made a very good impact and is building a fine reputation internationally.

*Productivity*
The group has a very good publication record in terms of numbers as well as in terms of quality of the journal. The papers are well cited. The leader and members of the group won prestigious research grants. A concern is the moderate number of PhD's in relation to the number of permanent senior staff.

*Relevance*
Relative to its size, the programme collaborates with an impressive number of top institutions world-wide. The theoretical and experimental expertise and the extra-ordinary facilities of the programme are of interest both academically and for industry developing new or improved functional materials. This is also expressed by the diversity of positions that the members of the group (post-docs and doctoral students) occupy once they leave the university.

*Viability*
A clear and dynamic programme headed by a dynamic director and with young staff and clear short term and mid term objectives. Becoming part of the DelftChemTech department has been an important positive development during the period of evaluation.

**Conclusion**
The programme provides a convincing example of the high effectiveness that can be obtained due to the physical proximity between a group of physicists with substantial expertise in complex functional (electronic and electro-optic) properties and capable chemists who produce the high-quality complex functional materials.

The Committee was impressed by the dynamism of the head of the programme. While qualitatively the output of the group is very good, the Committee feels that additional impact can in the future be obtained by the already foreseen new equipment (ultra fast pulsed electron accelerator) and by a somewhat increased output. Taking into account the vision of the department to reinforce the internal collaborations between the various programmes and to translate the collaborations into source of strength and prominence, it is expected that the activity of the opto-electronic materials group will intensify, and its size, importance and impact will increase.

**Products & Process Engineering (PPE)**

| | | |
|---|---|---|
| Programme code: | TUD 11 | |
| Programme director: | Prof. dr. ir. M.T. Kreutzer | |
| Research staff 2007: | the staff was not active as such during the review period | |
| Assessments: | Quality: | NA |
| | Productivity: | NA |
| | Relevance: | NA |
| | Viability: | NA |

*Short description*
The field of Product and Process Engineering focuses on understanding and controlling the interplay of molecular kinetics, fluid mechanics and transport phenomena for the development of useful devices and processes.

The mission of the programme is to advance the understanding of engineering aspects that play a pivotal role in chemical conversions, and to use this understanding to creatively design new devices that allow to make materials that could not be made before, or to integrate a chemical conversion with other functions into a device, or to improve a synthesis process. The newly created programme focuses on three themes:

- Theme 1: Controlled synthesis of nanostructured materials
- Theme 2: Analysis and monitoring of chemical conversions
- Theme 3: Multiphase reaction engineering

*Quality*
The programme has been thoroughly reformulated in 2008 and two new leading staff members have been appointed. The new programme director has impressed the Committee with his enthusiasm and vision.

*Productivity*
The programme director and his assistant professor (J. R. van Ommen) have an excellent track record from their previous positions. This should be a solid base for a quick start with high productivity.

*Relevance*
The topic of Products & Process Engineering is a very broad one, and the themes proposed in the programme are highly relevant both for to the Department as well as for society. To advance all three programmes in parallel might put a too high strain on the group.

*Viability*
The three research themes mentioned should be a good starting base. Since the group has well established contacts to the other Programmes of the Department of Chemical Engineering as well as to the Department of Multiscale Physics it could also be helpful to better interconnect different disciplines. The main challenge for the group will be to establish its own research profile which focuses on a well chosen set of topics.

**Conclusion**
The programme is led by an enthusiastic young team with a number of interesting topics to pursue. It will certainly need several years and sufficient starting support to develop its own profile within the broad area of Products & Process Engineering, but the prospects are very promising.

**Self Assembling Systems (SAS)**

| | | |
|---|---|---|
| Programme code: | TUD 12 | |
| Programme director: | Prof. dr. J.H. van Esch | |
| Research staff 2007: | 4,9 fte | |
| Assessments: | Quality: | NA |
| | Productivity: | NA |
| | Relevance: | NA |
| | Viability: | NA |

*Short description*
The mission of the programme is to deliver leading research and education in the area of self-assembling systems, by investigating innovative concepts in the design and construction of functional nanostructured materials and devices, via the integration of synthetic methodologies, supramolecular and physical chemistry.

The aims of the programme will be addressed by following an approach in which molecular-based design and mesoscopic model developments are integrated, which requires the involvement of different expertises with each of the projects. Within these boundaries and opportunities the programme is developing the following themes:

- Theme 1: Self-assembled functional nanomaterials and devices
- Theme 2: Interfacial engineering
- Theme 3: Dynamic self-assembly and self-organisation.

*Quality*
SAS was created in 2007 to strengthen the mission of the Chemical Engineering department, which is now oriented to nano-chemistry. SAS started with the appointment of a section leader previously active in another university (Groningen) and with a major focus on self-assembling systems. A strong position in synthetic organic chemistry, supramolecular chemistry and colloid and surface science will guarantee SAS success in a challenging programme and thus in the quality of the output.

*Productivity*
Based on the bibliometric data reported for the staff members as a whole, the Committee is confident that the productivity will be very good if not excellent.

*Relevance*
The research programme has been established with a clear vision of scientific problems and application potential. Controlling the spatial position of chemical entities in self-assembled nano-architectures is a major issue which is tackled with the purpose to trigger desired functions (theme 1). Theme 2 falls in the field of self-assembly at the mesoscopic level, with the ambition to prepare self-assembled nanostructured electrodes for fuel-cells and surface-confined foldamers for nano-patterning. Last but not least, self-organisation in dissipative systems is under exploration not only for a better understanding of an essential characteristic of life, but also for designing responsive nano-objects and light-induced dynamic patterns. Conceptual innovation is thus formulated in timely topics in functional nanomaterials, nanodevices and nanoprocesses.

*Viability*
All the conditions are met for quality research of carried out by a rapidly growing group led by prominent scientists driven by interesting prospects in basic and applied science.

**Conclusion**
Future success of this new promising group strongly depends on how close it will stick to an appealing research programme built up on clear focus, coherence and innovative concepts.

## 3.5. Department of Multi-Scale Physics (MSP), TU Delft

### Introduction

The Department of Multi-Scale Physics (MSP) investigates flow and transport phenomena over a wide range of time and length scales in their mutual dependence. The research programme focuses on the interaction of molecular transport of heat and mass, chemical reactions, turbulent eddies, bubbles, drops and particles, and flow and convective transport at the scale of a process vessel. To this end the programme develops and exploits a wide variety of models and computational and experimental tools. The Department was formed in 2002 and operates as a single Department with no further subdivision into separate programmes. The single programme is divided into the following five themes, each headed by a full professor:

- Computational Reactor Engineering (headed by H. E. A. van den Akker)
- Multiphase Flows (headed by R. F. Mudde)
- Thermal & Materials Processes (headed by C. R. Klein)
- Reactive Flows & Explosions (headed by D.J.E.M. Roekaerts)

and the newly founded theme "Clouds, Climate & Air Quality", headed by H.J.J. Jonker, which is not included in the evaluation.

### Leadership

The Head of the Department is Prof. dr. ir. H.E.A. van den Akker, who has been the Scientific Director of the Dutch Research School in Process Technology (OSPT) since 2001. The Head of the Department is responsible for the quality and quantity of the personnel input in education and research, for the overall quality of the research and for the departmental budget. The Head of the department also bears the overall responsibility for the Department, is member of the Faculty Management Team and reports to the Dean of Applied Sciences. The theme leaders form the Management Team, which is supported by the Department Executive Secretary. The Management Team decides on strategic issues concerning research, education, finances, personnel and organisation.

The general policy is that the theme leaders should give room, support and freedom to the assistant and associate professors for the sake of their personal development and growth. Among other things, this implies that the theme leaders may leave certain initiatives, such a preparing research proposals and submitting journal papers, to the individual staff members. When considered necessary, however, the theme leader will provide advice or guidance. Similarly, this agreement is made between the assistant and associate professors and the PhD students. PhD students regularly meet with his/her 'promotor'.

### Mission & Goals

The mission of the Department is to develop the conceptual understanding and science of fluid dynamics (including turbulence and multi-phase flows) and transport phenomena at all relevant time and length scales as occurring in a wide variety of industrial (and environmental) processes. This improved understanding may result in better designs of process equipment, in a more precise control of the processes and operations involved and in a better performance of these.

The Department wishes to contribute to a more sustainable earth, and considers engineers to have a societal responsibility to contribute to realize major switchovers in energy use, raw

material consumption and CO2 discharge. The Department aims at developing insights and tools for designing substantially more sustainable processes in the base, fine and specialty chemicals business, as well as in energy conversion and materials processing. Scientific research is driven by industrial and societal challenges.

The topics addressed by the Department are technological; the approach is a mixture of modelling, computational simulations and experiments.

**Strategy & Policy**
The expertise of the Department – flow and transport phenomena – is an essential element of chemical engineering, as very often processes suffer from resistances to heat and mass transfer and from improper degrees of mixing and separation. Developing a better fundamental understanding of flow and transport phenomena at the various time and length scales and their mutual interaction is considered to be required for the purpose of reducing or eliminating transfer resistances and for improving mixing and separation. Both the experimental expertise and the advanced computational capabilities of the Department are instrumental for realising the ambitions..

The future emphasis of the Departments research will remain on contributing to improving the rather classical (chemical) process industries by developing a multi-scale approach that really takes the micro-scale events and processes into account. The lasting focus on the current process industries is prompted by the expectation that in the next 30 to 50 years the current type of chemical processes will remain dominating.

**Evaluative remarks about Leadership, Mission & Goals and Strategy & Policy**
The department is headed by a highly experienced and internationally well known scientist and expert in multiphase flow. It has been formed by the merger of two well established research groups in thermal and fluid sciences and in transport phenomena in order to obtain maximum synergy and to combine competence for all engineering and environmental systems which are described by Navier Stokes equations.
This can be considered a rather unique approach, but presently the synergies between the different themes (except for Multi-Phase Flows and Computational Reactor Engineering) are not too obvious. In particular the themes of “Reactive Flows & Explosions” and the newly founded theme “Clouds, Climate & Air Quality” (which is explicitly outside the scope of this evaluation) seem to diverge in substance from the other themes of Chemical Engineering covered in this review. Although there are some contacts to the group of Product and Process Engineering (TUD 11), a substantially closer cooperation with the Departments of Biotechnology and of Chemical Engineering in the areas of multiphase reactors and fermenters should be strived for in the future.

**Resources**
Table 3.9. provides an overview of the research staff at department level. This is similar to the programme level.

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** |
|---|---|---|---|---|---|---|---|
| Tenured staff | 3,8 | 4,3 | 4,4 | 4,4 | 4,4 | 4,4 | 4,1 |
| Non-tenured staff | 3,6 | 5,6 | 5,9 | 4,7 | 4,8 | 5,4 | 4,2 |
| PhD students | 16,4 | 20,4 | 18,5 | 17,1 | 14,4 | 12,0 | 10,7 |
| **Total research staff** | **23,7** | **30,3** | **28,8** | **26,2** | **23,6** | **21,9** | **19,1** |

Table 3.5.1. Staff at department level (in research fte)

The Department is 'in transition' due to the departure of several professors between 2005 and 2007. These circumstances have created an opportunity to rejuvenate and two very promising, young assistant professors were hired and a part-time full professor was installed as well. Hiring decisions were balanced between strengthening the Departments footprint and finding excellent candidates for a tenure track position with an own view and expertise. Hiring was also done on the basis of the candidate's ability to contribute to the industrial and societal connections. For PhD students there is a well described hiring process. As far as HRM issues are concerned, the Department follows the policies of the Faculty of Applied Sciences.

Highly qualified technical support staff is essential in view of the advanced laser and radiation-based experimental techniques and because of the pilot-plant facilities. The support staff safeguards the basic technical expertise and supervises safety.

**Funding policies and Facilities**

Table 3.5.2 provides an overview of the funding resources and expenditure at institutional level. Financial prospects of future years are less positive compared to the present situation, due to a reduction in University funding. The Departments has been successful over the past years in participating in university programmes. From several organizations research funding is acquired and PhD projects are often granted by STW with the usual support from industry. Several postdocs and PhD students were also funded by industry and research industries. Industries have been financially helpful in acquiring experimental setups.

| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % | M€ | % |
| **Funding** | | | | | | | | | | | | | | |
| Direct Funding | 0,7 | 64 | 2,2 | 69 | 3,1 | 71 | 2,7 | 82 | 2,8 | 68 | 2,8 | 74 | 3,0 | 77 |
| Research Funds | 0,4 | 36 | 0,6 | 19 | 0,7 | 16 | 0,4 | 12 | 0,5 | 12 | 0,4 | 11 | 0,3 | 8 |
| Contracts | 0,0 | -9,1 | 0,3 | 9 | 0,5 | 11 | 0,2 | 6 | 0,7 | 17 | 0,4 | 11 | 0,5 | 13 |
| Other | 0,1 | 9,1 | 0,1 | 3 | 0,1 | 2 | 0,0 | 0 | 0,1 | 2 | 0,2 | 5 | 0,1 | 3 |
| *Total funding* | **1,2** | **100** | **3,2** | **100** | **4,4** | **100** | **3,3** | **100** | **4,1** | **100** | **3,8** | **101** | **3,9** | **101** |
| **Expenditure** | | | | | | | | | | | | | | |
| Personnel Costs | 2,9 | 85 | 2,2 | 63 | 3,6 | 77 | 2,9 | 81 | 3,1 | 77 | 2,8 | 87 | 2,6 | 90 |
| Other costs | 0,5 | 15 | 1,3 | 37 | 1,1 | 23 | 0,7 | 19 | 0,9 | 23 | 0,4 | 13 | 0,3 | 10 |
| *Total expenditures* | **3,4** | **100** | **3,5** | **100** | **4,7** | **100** | **3,6** | **100** | **4,0** | **100** | **3,2** | **100** | **2,9** | **100** |

Table 3.5.2. Funding and expenditure at the departmental level

At present the Department is housed in two buildings, but in mid 2009 a new office building will be available. Also an existing hall is being remodelled to house experimental test rigs.

**Evaluative remarks about Resources, Funding policies and Facilities**

Compared to the two other Delft departments described in this report, this department is substantially smaller (about 30% of the size of the others). It also gets relatively fewer funds from contracts (about 12% of total expenditures, compared to over 24% for the others).
Due to past investments, the experimental facilities still seem to be very good but may become outdated in the future if major investments will dwindle and highly qualified technical support staff is not replaced.

**Academic Reputation**
Previous peer reviews were held in 2002 (Research Assessment Chemistry & Chemical Engineering) and over the period 1998-2002 (Research Assessment Applied Physics Delft & Physics Leiden). Furthermore, the self-evaluation provides a list of activities of the faculty members (i.e. reviewer for scientific journals, acting member of scientific committees, invited as a speaker at conferences, symposia and companies). Table 3.5.3 provides an overview of the CWTS Bibliometric Study between 1997-2006.

Table 3.11. provides an overview of the CWTS Bibliometric Study between 1997-2006:

| Period | P | CPPex | JCSm | FCSm | CPP/ JCSm | sign. | CPP/ FCSm | sign. | JCSm/ FCSm |
|---|---|---|---|---|---|---|---|---|---|
| 1997-2006 | 222 | 4,56 | 3,49 | 2,93 | 1,31 | + | 1,56 | + | 1,16 |

**Evaluative remarks about Academic Reputation**
The Academic Reputation as demonstrated by the publications over the reporting period can be considered very good. But with the retirement of Hanjalic in 2005 one main contributor to this reputation will no longer be active. The number of PhD students has been comparatively low and continue to drop. In the past (2001 and 2002) the majority of PhD students did not finish within 5 years.

**Societal Relevance**
The research of the Department is directly linked to and relevant for major developments in society. Sustainability and economy driven issues are central themes for the Department and topics of great interest to society. The Department contributes to developments in these areas by supporting developments at (chemical) process industries and in the field of energy production. In this respect, the Department contributes by developing novel smart technologies and by improving existing processes.

**Evaluative remarks about Societal Relevance**
Expertise in Fluid Flow and Transport Phenomena is a basic requirement for research and education in all fields of Chemical Engineering. In this respect the department's expertise is essential for TUD. A clearer vision of how the department can contribute to and participate in the activities of the Process Technology Platform of TUD would be welcome.

**Balance of Strengths & Weaknesses**
The self-evaluation report contains a SWOT-analysis with the following main points:

*Strengths*
- Strong mix of experimental, modelling and simulation expertise embodied in sophisticated techniques
- Excellent and unique experimental facilities
- Excellent computational expertise, particular in Lattice-Boltzmann techniques
- Strong reputation in the fields of fluid mechanics, transport phenomena & chemical (reaction) engineering
- Synergy between MPS themes
- Well-developed contacts with leading companies
- Flat organization with ample room for individual faculty
- Complementary research groups in the fields of fluid mechanics and chemical engineering located nearby

*Weaknesses*
- Difficulty in attracting sufficient numbers of good PhD students
- Housing spread over two different locations

*Opportunities*
- Promising new topics: flameless combustion, micro-fluidics & micro-reactors, magneto-hydrodynamics including magnetic drug targeting, X-ray tomography, environmental issues, clouds & climate
- Recent expansion in faculty, with 2 new part-time professors appointed
- Increased involvement in new MSc programme Chemical Engineering
- Increased interest in society for sustainability and energy issues
- Moving to new premises (2010) allowing for stronger interaction among MSP faculty

*Threats*
- Field of Chemical Engineering being misconceived in academia as an 'old-fashioned discipline'
- Risk of too wide spread in applications/fields of interest
- Faculty feeling less at ease or hesitating to join due to strong emphasis from HRM on personal competencies
- Tendency towards individualism within Department

**Evaluative remarks about Strengths and Weaknesses**
The potential strength of the department certainly lies in its combined focus on fluid flow and transport phenomena, in its great expertise in related modelling and simulation techniques and in its excellent experimental equipment for flow visualization. It is therefore rather surprising that the co-operation with neighbouring departments, in particular in the area of multiphase flow in fermenters and bioreactors or in chemical reactors seems very limited. This leads to the impression that the department is not sufficiently integrated. A clearer vision of its future role in and its contribution to the Process Technology Platform of TUD would therefore be welcome.

## 3.6. Assessment per programme: Department of Multiscale Physics (MSP), TU Delft

**Multi-Scale Physics**

| | | |
|---|---|---|
| Programme number: | TUD 13 | |
| Programme director: | Prof. dr. H.E.A. van den Akker | |
| Research staff 2007: | 19,06 fte | |
| Assessments: | Quality: | 3 |
| | Productivity: | 4 |
| | Relevance: | 3 |
| | Viability: | 3 |

*Short description*
The programme focuses on the interaction of molecular transport of heat and mass with chemical reactions, on turbulent eddies, bubbles, drops and particles, and on flow and convective transport at the scale of a process vessel. The programme has five themes, each headed by a full professor:

- Computational Reactor Engineering (headed by H. E. A. van den Akker)
- Multiphase Flows (headed by R.F. Mudde)
- Thermal & Materials Processes (headed by C.R. Klein)
- Reactive Flows & Explosions (headed by D.J.E.M. Roekaerts)
- Clouds, Climate & Air Quality, headed by H.J.J. Jonker (newly founded, not included in this evaluation).

*Quality*
The overall quality of the programme is considered good, with larger differences between the four themes considered. The coherence and the cooperation between the first three themes and the two others seems to be restricted to the common use of Navier-Stokes equations, but the application areas are far apart..

*Productivity*
The overall productivity of the scientists involved in the programme has been very good. This applies in particular to publications in well known scientific journals. The number of PhD students finished as well as the time required to finish a PhD could be improved in the future.

*Relevance*
Multiscale Physics as defined by the programme is and remains of potentially eminent importance in many fields of Chemical and Bio-Engineering. The Committee got the impression that this potential is obviously not in demand or realized as there is very little collaboration and/or interaction with other potentially interested groups in the other departments.

*Viability*
The Committee was not convinced that the present combination of the five themes into a separate, relatively small department is a particularly viable option for its future development. The Committee therefore suggests considering integration of the different themes into departments where they are closer to potential “users”

**Conclusion**
Although the expertise provided by the programme should be of relevance for TU Delft, it presently seems not to be sufficiently accessible to and/or utilized by other departments. It should therefore be discussed whether some reorganization would be of advantage.

# 4. University of Twente

## 4.1. Faculty of Science and Technology, Discipline of Chemical Engineering

**Introduction**
The Department of Chemical Engineering has existed since the foundation of the University of Twente in 1961. In 2002 it merged with Applied Physics into the Faculty of Science and Technology. The research activities of the Chemical Engineering Discipline are embedded in three Research Institutes of the University of Twente:

- Institute for Nanotechnology MESA+
  MESA+ focuses on nanotechnology based on its underlying strengths in materials science, micro- system technology, bottom-up chemistry, optics and systems.
- Institute for Mechanics, Processes and Control Twente: IMPACT
  The research of IMPACT enables the creation and subsequent optimization of (new) products, processes and methods, improve sustainability, reduce environmental imprints of processes and products.
- Institute for Biomedical Technology: BMTI
  BMTI performs research and design activities in integrated biomedical engineering for restoration of human function. As from January 1st 2009, BMTI has been merged into a larger institute BMT-TM: Institute for Bio-medical Technology and Technical Medicine.

**Leadership**
The Faculty of Science and Technology (TNW) is rooted in two Disciplines: Chemical Engineering and Applied Physics. The Faculty is led by a professional Dean assisted by a Managing Director and a Financial Controller. The Faculty is responsible for the bachelor and master curricula of the two monodisciplines and in addition hosts multidisciplinary curricula, which are offered in co-operation with other faculties.

The Research Institutes are managed by a Scientific Director, assisted by a Technical Commercial Director. All Research Institutes have a Supervisory Board as well as an Advisory Board, in which external governors and scientists participate.

The Discipline is a recognizable unit in the Faculty led by a Discipline Coordinator who chairs the Discipline Council meeting once a month. The Discipline Council is an instrument to coordinate and initiate improvement processes, in particular on educational activities. The Discipline Coordinator has no formal responsibility, but acts as a facilitator within the Discipline.

The responsibilities are allocated as follows:

- The Faculties are responsible for the educational programmes, the integral budget, financial administration, human resources and safety
- The Research Institutes are responsible for the strategic research orientations, including the programming of the multidisciplinary research activities across classical disciplines
- The Chair Holders are responsible for the research focus and performance as well as the quality of the education in their field. The staff of the Chair is employed by the Faculty.

This 'matrix structure' Programmes and Institutes is intended to serve the following purposes:

- create added value in comparison with monodisciplinary Research Institutes and stimulate inter-disciplinary research;
- offer the opportunity to (a) focus on grand global challenges and (b) align with external stakeholders and resources;
- realize sufficient critical mass and international visibility in strategically identified fields;
- offer disciplinary depth for a portfolio of sub-disciplines;
- embed Chairs in a homogenous collection of Disciplines without strong boundaries.

Within the Research Institutes the programmes are organised by programme leaders. Their task is to:

- create focus and visibility for the working programme, internally and externally;
- establish detailed working programmes in close contact with the participating Chairs through organisation of internal workshops, etc;
- establish links to important funding agencies;
- co-ordination with respect to the related 3TU-IST Centres of Competence and embedded Centres of Excellence;
- development and implementation of an effective PR strategy.

**Mission & Goals**
The mission of the Discipline of Chemical Engineering is:
'to develop, disseminate and apply innovating knowledge of high standards as well as to inspire and educate students at an internationally renowned level, in three multidisciplinary areas: molecular nano-science, biomedical material sciences and sustainable process technology.'

**Strategy & Policy**
Twente University developed a pronounced profile as an entrepreneurial university with a tradition in interdisciplinary research and education in the technical as well as social sciences. The Department of Chemical Engineering was based on three main research orientations: basic chemistry, material sciences and process technology. In 2002 the Department of Chemical Technology merged with Applied Physics into the Faculty of Science and Technology.

In 2006, as a consequence of the shifting areas of interest as well as financial pressure, a reorganisation process was initiated. Three new main research topics were chosen within the Discipline Chemical Engineering: supramolecular chemistry & nanotechnology, biomaterials & tissue engineering, and sustainable processes. In the reorganisation, some Chairs were discontinued or migrated to the Faculty of Engineering Technology.

In the context of the three Technological Universities (3TU) in the Netherlands, a number of 3TU Centres of Excellence were defined with the aim to improve the mutual cooperation and matching between the Dutch technical universities and to obtain a larger critical mass for research. The Discipline of Chemical Engineering participates in three of these centres: Bionano Applications, Fluids and Solids and Sustainable Energy. These centres and upcoming large national programmes facilitated the funding of new Chairs.

To be prepared for the future, Twente University aims to attract, develop and keep more top talent by means of several measures, such as the establishment of an international graduate school, an appropriate scouting policy, introduction of tenure track positions for young staff, appointments under more flexible conditions and extra rewarding of outstanding staff.

**Evaluative remarks about Leadership, Mission & Goals and Strategy & Policy**
Twente University has chosen a structure that gives the leadership to the Faculty Dean and to the Directors of the 3 Transversal Institutes, while the Discipline has a Coordinator with no formal authority who acts as a facilitator: the matrix structure with the Research Institutes gives a clear added value in bringing the chairs of the discipline closer together, stimulating or enhancing collaborations within the discipline and across disciplines. In the Discipline of chemical engineering itself, a dynamic and collegial atmosphere is noticed, which is promoted by the director, and is highly conducive to effective research and training of PhD students. There is a certain concern that without a clear leadership-role by the director of the discipline, the long-term goals will not be reached in an optimal fashion.
The Committee notes that the mission of the discipline has evolved from the wider areas of process technology, materials technology and material science and molecular technology/ chemistry, as defined in 2002, to materials nano-science, biomedical material sciences and sustainable process technology. The challenge of replacements for retiring professors that the discipline faced in the last few years has been answered by new faculty who helped refine the mission toward timely and emerging areas. The Discipline now enjoys an optimal age distribution in the leading positions and excellent atmosphere and facilities for research. The well balanced mix of fundamental and basic application-motivated research and a proactive recruitment policy for students and PhD's as presented by the discipline appear to be suitable strategy to face the general problem of low interest in engineering among young people.

**Resources, funding policies and facilities**
Table 4.1. provides an overview of the research staff at department level. In table 4.2. the research staff for each programme is provided. Table 4.3. provides an overview of the funding resources and expenditure at institutional level.

The Faculty of Science and Technology is a research faculty which becomes apparent from the 1:4 ratio between education and research income of research groups, instead of the average 1:2, for the entire University of Twente. The income from research funds or contracts is relatively large and determines almost 50% of the funding.

The gross budget of the Discipline increased from M€ 12,5 to M€ 23 in the period 2001-2007. This is an increase of approximately 84% in a seven-year period. (around 70% when corrected for inflation). This increase is directly related to the growth in research of the Discipline, especially the growth in the programmes for Biomaterials & Tissue Engineering in 2005 and Separation Technology in 2006. The indirect funding (research funds and contracts) has increased substantially during the evaluation period from 38% to 47% of the gross budget. The expenditures for personnel increased steadily by half a million Euros a year, resulting in an increase of 56% over the total period. This increase can be explained by the expansion of the staff (45%) and inflation (14 %). From 2004 to 2006, the large growth of the housing costs was centrally compensated. After 2006 the costs of housing doubled.

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|
| tenured staff | 15,3 | 15,7 | 17,1 | 18,3 | 17,7 | 16,8 |
| non-tenured staff | 20,7 | 19,6 | 27,1 | 32,5 | 38,0 | 34,5 |
| PhD students | 71,1 | 74,2 | 82,3 | 84,4 | 90,5 | 94,4 |
| **Total research staff** | **107,1** | **109,4** | **126,5** | **135,1** | **146,2** | **145,7** |

Table 4.1.: Research staff at institute level

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|
| **Biomaterials & Tissue Engineering** | | | | | | |
| tenured staff | 2,8 | 3,4 | 4,2 | 5,4 | 4,7 | 4,5 |
| non-tenured staff | 2,0 | 1,8 | 6,6 | 9,4 | 13,6 | 9,4 |
| PhD students | 12,6 | 11,5 | 17,8 | 21,2 | 23,5 | 24,4 |
| Total research staff | 17,3 | 16,7 | 28,6 | 36,0 | 41,8 | 38,4 |
| **Catalytic Systems & Microdevices** | | | | | | |
| tenured staff | 1,8 | 2,1 | 2,15 | 2,0 | 1,9 | 2,2 |
| non-tenured staff | 4,6 | 3,3 | 2,65 | 3,4 | 3,1 | 2,4 |
| PhD students | 6,7 | 6,0 | 7,56 | 8,3 | 10,4 | 12,3 |
| Total research staff | 13,1 | 11,4 | 12,36 | 13,6 | 15,3 | 16,8 |
| **Chemical Reaction Engineering** | | | | | | |
| tenured staff | 2,0 | 2,0 | 2,0 | 2,0 | 1,9 | 1,7 |
| non-tenured staff | 1,1 | 2,6 | 3,4 | 1,4 | 1,0 | 1,4 |
| PhD students | 7,9 | 7,9 | 8,1 | 8,3 | 8,1 | 9,1 |
| Total research staff | 11,1 | 12,5 | 13,5 | 11,6 | 11,0 | 12,2 |
| **Inorganic Material Sciences** | | | | | | |
| tenured staff | 2,25 | 3 | 3,12 | 2,92 | 2,46 | 1,66 |
| non-tenured staff | 2,27 | 3,6 | 5,82 | 9,5 | 7,45 | 5,85 |
| PhD students | 7,76 | 10,77 | 12,43 | 11,15 | 10,54 | 10,73 |
| Total research staff | 12,28 | 17,37 | 21,37 | 23,57 | 20,45 | 18,24 |
| **Organic Material Sciences** | | | | | | |
| tenured staff | 1,9 | 1,7 | 1,6 | 1,6 | 1,6 | 1,6 |
| post-docs | 2,0 | 1,7 | 0,4 | 2,0 | 3,7 | 2,5 |
| PhD students | 9,3 | 9,7 | 7,9 | 8,2 | 8,0 | 6,6 |
| Total research staff | 13,1 | 13,1 | 9,9 | 11,8 | 13,3 | 10,7 |
| **Separation Technology** | | | | | | |
| tenured staff | 1,7 | 1,0 | 1,5 | 1,6 | 2,5 | 3,1 |
| non-tenured staff | 3,2 | 3,3 | 3,0 | 2,4 | 3,4 | 5,7 |
| PhD students | 10,2 | 12,3 | 13,8 | 14,6 | 16,7 | 20,0 |
| Total research staff | 15,0 | 16,6 | 18,3 | 18,6 | 22,6 | 28,8 |
| **Supramolecular Engineering** | | | | | | |
| tenured staff | 2,9 | 2,5 | 2,5 | 2,8 | 2,7 | 2,0 |
| non-tenured staff | 5,5 | 3,3 | 5,3 | 4,5 | 5,8 | 7,4 |
| PhD students | 16,8 | 16,0 | 14,8 | 12,7 | 13,3 | 11,3 |
| Total research staff | 25,2 | 21,9 | 22,5 | 19,9 | 21,8 | 20,7 |
| **Total research staff** | **107,1** | **109,4** | **126,5** | **135,2** | **146,2** | **145,7** |

Table 4.2. Research staff at research programme level

All Chairs have lab facilities. The University started a process of major renovations of its infrastructure in 2000. BMTI and IMPACT have renewed laboratory facilities. MESA+ NanoLab has extensive laboratory facilities at its disposal, offering a wide spectrum of opportunities for researchers in the Netherlands and abroad, such as a fully equipped clean room, with a focus on microsystems technology, nanotechnology, CMOS and materials and process engineering, a fully equipped central materials analysis laboratory, a number of specialized laboratories for chemical synthesis and analysis, materials research and analysis, and device characterization. In 2009 all MESA+ facilities will be centralised in one new building, which will include a completely new clean room facility. The investment in the new clean room amounts to about 40 million Euro.

| | | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Funding* | | k€ | % | k€ | % | k€ | % | k€ | % | k€ | % | k€ | % |
| | Direct Funding | 8,3 | 62 | 8,4 | 59 | 8,9 | 55 | 9,4 | 50 | 13,1 | 54 | 12,3 | 53 |
| | Research Funds | 2,6 | 20 | 3,0 | 21 | 4,2 | 26 | 4,9 | 26 | 4,6 | 25 | 5,5 | 24 |
| | Contracts | 2,4 | 18 | 2,8 | 20 | 3,1 | 19 | 4,5 | 24 | 4,4 | 21 | 5,3 | 23 |
| **Total Funding** | | **13,4** | **100** | **14,2** | **100** | **16,3** | **100** | **18,8** | **100** | **22,1** | **100** | **23,1** | **100** |
| *Expenditure* | | | | | | | | | | | | | |
| | Personnel Costs | 8,1 | 61 | 8,6 | 61 | 10,1 | 62 | 10,8 | 58 | 12 | 54 | 11,7 | 51 |
| | Housing costs | 1,1 | 8 | 1,1 | 8 | 1,1 | 7 | 0,7 | 4 | 1 | 4 | 2,4 | 10 |
| | Other Costs | 4,2 | 31 | 4,5 | 32 | 5,1 | 31 | 7,3 | 39 | 9,2 | 42 | 9,1 | 39 |
| **Total expenditure** | | **13,4** | **100** | **14,2** | **100** | **16,3** | **100** | **18,8** | **100** | **22,1** | **100** | **23,1** | **100** |

Table 4.3. Institute's funding and expenditure at institutional level.

**Evaluative remarks about Resources, Funding policies and Facilities**
The facilities are first rate. The matrix structure allows the programmes to benefit from the extra-ordinary facilities of the research institutes. A concern is the future capacity to finance continuous improvements to keep the facilities state-of-the-art. It is remarked that the Institutes intend to increase second and third money stream to become less dependent on direct funding. On the other hand, the programme directors expressed concern that the first budget stream, coming from the University, is primarily output based, which does not encourage initiatives of the discipline or the individual chairs. The Committee agrees with this concern.

**Academic Reputation**
All groups have attracted research funds from national and international scientific programmes. The tenured staff and PhD students publish their work in refereed journals and present contributions at numerous international conferences. The impact scores of the publications are above 1.5 for all programmes.

In the 'attraction index' of the Dutch Rathenau Institute, which indicates the degree in which a university succeeds in acquiring external funds for research fte's, the University of Twente, as one of the thirteen Dutch universities, scores first in attractiveness for research funding and third for contracts.

Most chair-holders of the Discipline are member of the national or international boards in their research area. Many staff members of the Discipline are member of editorial boards of international refereed journal, and are international jury member of funding and grant organisations, invited speaker at international conferences, member of organising Committees of

international conferences, examiner for international dissertations or lecturer at international PhD courses.

**Evaluative remarks about Academic Reputation**
Most of the programmes of the discipline have an internationally leading position and all parameters indicate a high recognition. The Discipline has successfully overcome the period of retirements and reorientation of the last 10 years and the results in term of impact and recognition are excellent and show potential for further enhancement.

**Societal Relevance**
The self-evaluation report states that the research portfolio addressed by Chemical Engineering in Twente is fully in line with the social need in this domain, and is therefore ideally suited for educating the top level personnel required by society at this time.

**Evaluative remarks about Societal Relevance**
university and the discipline designed the overall research profile has with societal relevance as an important criterion. As a result, the discipline is organized to answer the needs of society via research in fields such as  energy, health and water.

**Balance of Strengths & Weaknesses**
The institute has provided a SWOT-analysis with the following main points:

*Strengths*
- The matrix organisation with separate Research Institutes and Faculties has proven to be a successful concept for interdisciplinary and multidisciplinary research.
- The renewed infrastructure, especially the recently opened buildings for the institutes BMTI and IMPACT in 2007 and the realisation of a new accommodation for MESA+ in 2009, offer an optimal research environment.
- The age distribution of academic staff is well-balanced with several young chemists appointed at key junior faculty positions.
- The research portfolio addressed by Chemical Engineering in Twente is fully in line with the social need in this domain, and is thereby ideally suited for educating the top level personnel required by society at this time.

*Weaknesses*
- A well-operating matrix organisation requires considerable attention for the internal communication processes.
- Following the (inter)national research agenda does not necessarily stimulate the long term coherence and development of the discipline.
- To safeguard the continuity of the research programme, the staff has to put much effort into writing proposals for the various funding agencies.

*Opportunities*
- The research of the Discipline of Chemical Engineering focuses on three areas: Material sciences and nanotechnology, Sustainable chemistry and technology, and Biomedical technology. These are technologies of the future and are in line with the recently published Action Plan and Business Plan of the national Direction Group Chemistry (Regiegroep Chemie).
- The focus areas of Chemical Engineering are explicitly mentioned as key research areas in the strategic plan of the University of Twente.

- Strategic Research Orientations of the Research Institutes offer the opportunity to combine expertise of different groups and to explore new areas.
- The co-operation, adjustment and integration within the 3TU federation (especially the 3TU Centres of Excellence and Centres of Competence) will strengthen the national and international position and visibility of the three Technical Universities in the Netherlands and consequently the position of the Discipline in Twente.

*Threats*
- In the matrix research organisations, a tension is noticeable between monodisciplinary quality and the creation of sufficient critical mass for inter- and multidisciplinary research.
- Discussion between Institutes and Faculties on research themes and educational programmes might lead to conflicts of interest.
- The small number of student in Chemical Engineering, which is a broad phenomenon in western society, may weaken the position of the discipline at the University.
- Budget cuts (or budgets not keeping up with rising costs) may undermine attracting top talent, improvement of infrastructure, innovation of research and ultimately morale.
- A strong focus on external projects might shift research predominantly to short term issues in lieu of fundamental research.
- Full output based financing creates an accountability problem and a mindset of reporting/calculating/administrating instead of attention for the primary processes.

*Analysis*
- The current position of the Discipline with regard to the research focal areas, organisation and infrastructure is a fertile basis for the future. Programme development within Research Institutes secures critical mass, embedding and improved possibilities for influencing (inter)national research agendas.
- The University and the Discipline wants to be prepared for new future opportunities, social developments and changes in the financial funding structure. Therefore, the organisation intends to increase the so-called second and third money stream and to become less dependent on direct funding. As an example, initiatives can be mentioned to stimulate academic staff to obtain Veni, Vidi or Vici grants (from NWO) and extra funding through the national action plan for (increased) Chemistry and Physics. Also the cooperation with third parties is strengthened.
- The University of Twente aims to attract, develop and keep more top talent by means of the establishment of an international graduate school, an appropriate scouting policy, and introduction of tenure track positions for young staff, appointments under more flexible conditions and extra rewarding of outstanding staff.
- To increase the enrolment of bachelor students, several initiatives are taken to bring young students of the secondary schools into contact with science in a playful manner and to involve more senior students directly in the education at the University.

**Evaluative remarks about the SWOT-analysis**
The Committee appreciates the successful transition from the established to a new generation of leading professors and staff as well as the restructuring and the extensive infrastructure build-up that the discipline underwent in the last few years, and the extensive building-up of the infrastructure. The discipline demonstrated an excellent academic quality, relevance and viability and a very good productivity according to international standards.

The SWOT analysis about the strength of the discipline is supported by the Committee. The weakness analysis points to one real challenge that needs to be answered by the Discipline and the Deanship, namely the possible inconsistency between the (inter)national research agenda and that which might be the more ideal agenda for the discipline with respect to coherence, development, and future perspectives. This is also rightly listed in the first two items under 'treats'. The powerful three transversal institutes, which are a unique source of strength and might be used as a model for other universities, could be reinforced by a stronger position for the heads of the two disciplines (chemical engineering and applied physics): a stronger say in the long term planning, some control in allocating funds from the university to the individual programmes, etc.

Finally, the absence of even a single female in a position of a programme director is regrettable in particular given that the discipline of chemical engineering (world-wide) traditionally does not lack female excellence at the student, graduate student, junior researcher and professor levels.

### 4.2. Assessment per programme – Twente University

The Committee assessed the following programmes of the Discipline of Chemical Engineering at Twente University:

| | Quality | Productivity | Relevance | Viability |
|---|---|---|---|---|
| **Research programmes** | | | | |
| UT 1 Biomaterials & Tissue Engineering | 5 | 5 | 5 | 5 |
| UT 2 Catalytic Systems & Microdevices | 3 | 3 | 4 | 3 |
| UT 3 Chemical Reaction Engineering | 5 | 4 | 5 | 4 |
| UT 4 Inorganic Materials Science | 5 | 4 | 5 | 5 |
| UT 5 Organic Materials Science | 5 | 5 | 5 | 4 |
| UT 6 Separation Technology | 5 | 4 | 5 | 4 |
| UT 7 Supramolecular Engineering | 5 | 5 | 5 | 4 |

The detailed assessment per programme follows in the next section of this report.

**Biomaterials & Tissue Engineering**

| | | |
|---|---|---|
| Programme code: | UT 1 | |
| Programme director: | Prof. dr. J. Feijen, Prof. dr. C.A. van Blitterswijk, Prof. dr. J.F.J. Engbersen (from 2005), Dr. R.J. Gaymans | |
| Research staff 2007: | 38,39 fte | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
In this research programme, advanced materials are designed to provide solutions in the diagnosis and treatment of health disorders and in substituting diseased tissues. In this field of research, where fundamental science is applied in medicine, delivery of drugs and growth factors (as well as genes) also play an important role. Three research groups investigate the interactions between (polymeric) biomaterials and cells and tissues. The research activities are organized in four themes: 1) Polymer chemistry and biomaterials, 2) Tissue engineering, 3) Controlled drug delivery and gene delivery, 4) Tissue regeneration.

*Quality*
Since the last evaluation in January 2000, the composition and research activities of the original Polymer Chemistry and Biomaterials (PBM) group have changed considerably. The size is now three times larger (from 12.5 fte in 2000 up to 38.9 fte in 2007), which makes the present programme the largest (26.5 %) in the Chemical Engineering discipline. This growth is the result of the strengthening of the original research activities of PBM by two additional strong expertises on targeted and controlled drug and gene delivery, on the one hand, and on tissue engineering and tissue regeneration, on the other. This evolution and the embedding of the new group in the large institute for Biomedical Technology and Technical Medicine, reinforces a position that was recognized as unique in the field of biomaterials in the Netherlands and seen as internationally very well-placed by the previous evaluation Committee.

*Productivity*
The publication strategy is very effective, leading to a number of papers and PhD theses in perfect balance with the size of the group (ca. 25 % of the whole production in Twente Chemical Engineering). The crown indicator is high (1.60 +), and the effort to publish in journals with a high impact should be sustained. The number of patents remains impressive as well as the number of spin-offs.

*Relevance*
The mission and goals are of high scientific and societal relevance. The research programme covers a very large front in an original and coherent way, which is the guarantee of a very significant and well-balanced (fundamental vs. applied) contribution to the field.

*Viability*
The size of the group increased significantly in parallel with the broadness of the research front. As of January 1st 2009, the programme leader, Prof. J. Feijen, retired. The search for a successor of Prof. Feijen has been initiated by the faculty. As director of the research institute

BMTI, Prof. Feijen was succeeded internally by Prof. C.A. van Blitterswijk. This transition was negotiated successfully. The excellence of the management is the best guarantee of the viability of the BTE programme.

**Conclusion**

The clear vision and ambitious views of the leadership have been rewarded by the impressive growth of the group, which has accordingly consolidated y its leading position in the Netherlands as well as its international competitive position This effort must be continued, focusing on fundamental innovation and publication in high impact journals.

**Catalytic Systems and Micro Devices (CSMD)**

| | | |
|---|---|---|
| Programme code: | UT 2 | |
| Programme director: | Prof. dr. H. Gardeniers, Prof. dr. ir. L. Lefferts | |
| Research staff 2007: | 16,79 | |
| Assessments: | Quality: | 3 |
| | Productivity: | 3 |
| | Relevance: | 4 |
| | Viability: | 3 |

*Short description*
The research area of the group is characterized as high precision chemical conversion. High precision is achieved via chemical means, using catalytic as well as alternative activation methods, requiring extensive analytical techniques and devices. Another approach is to control reaction conditions, i.e. concentrations of reactants / products, temperature, pressure, but also concentrations of intermediate (surface-)species; in-situ sensing and monitoring are being developed for that purpose. The programme consists of two research groups, i.e. Mesoscale Chemical Systems and Catalytic Processes and Materials.

*Quality*
The programme consists of two subprograms, trying to combine high precision chemical conversions with aspects of applied heterogeneous catalysis. The specific expertise in the respective programmes is adequate and is combined allowing efficient interactions. The approach involving design of new specific catalysts for use in microreactors, the implementation of the effect of microfluidics and the effort in process productivity is timely, innovative and from the industrial and fundamental point of view of high strategic value. The effective interaction of both groups up till now seems to be limited as suggested by the low number of joint publications, although there seems to be ample potential for an increasingly growing interaction and output. Normalised to other research fields, the group occasionally made valuable contributions to the field. They are regularly publishing their work into the better journals of the fields, though contributions in journals with broad general impact have been rather limited. The group is a well appreciated local player and occasionally attracts international attention for very specific items and expertises.

*Productivity*
The number of refereed international publications per full-time research equivalent is good and well above average, although it could stand further improvement. Recent data on publication output point to an enhanced productivity. The Committee recommends a significantly enhanced search for more good PhD students in combination with an increased degree of coaching to reduce the number of discontinuations. The Committee agrees that the performance level of the group has been limited in part due to chronic long-term illness of (a) staff member(s) and technical understaffing. Today, many elements seem to be present for realizing a significantly enhanced score in an area that offers technical as well as fundamental opportunities

*Relevance*
The relevance of the topics studied is very good and highly promising. Attention is focussed on concept development combined with practical implementation. The outlook of this approach

is very good. The topics on nanofabrication and micro-device should easily lead to the creation of one or more spin-out companies. The authors should continue their effort on interacting with selected industrial partners, allowing generating a portfolio of patents in combination with a very good or even excellent output.

*Viability*
The Committee recognizes a significant growth potential of quality and quantity of the output, given the new structure of unit, the increased number of PhD students and technical support staff. The programme directors are advised to provide dedicated and detailed coaching to each of the PhD students and to stimulate and promote interactions between individuals belonging to each of the two research programmes. The strategy of the new approach and selection of topics is highly relevant and harbours high growth potential.

**Conclusion**
The Committee feels that all potential necessary for this group becoming an internationally valued player is now inherently present. Tendencies are already visible today that the new programme which efficiently combines the expertise of the two groups should improve level of the group to that of a valuable international player. The Committee recommends that during this rather critical period and expected phase of steady growth, the degree of coaching of the PhD students should be intense and internal collaboration stimulated. The topics and their combination are highly timely and of high strategic importance for a sustainable production of fuels and chemicals.

**Chemical Reaction Engineering**

| | | |
|---|---|---|
| Programme code: | UT 3 | |
| Programme director: | Prof. dr .ir. H. Kuipers | |
| Research staff 2007: | 12,15 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The goal of this research group is the integration of fundamental research with applied engineering science in Chemical Reaction Engineering, with a broad view on reactor types which are relevant for the chemical industry. A particular focus lies on dispersed multiphase systems (gas-solid fluidized beds and gas-liquid bubble column reactors) as well as on novel reactor concepts, integrating membrane separation and efficient heat provision and recovery. Methodically, a close combination of detailed mathematical modelling and experimental analysis and verification is applied.

Concerning the common research areas identified by the 3TU-Federation, the group participates in the area of 'multi-scale phenomena in fluids and solids' and in 'sustainable energy'. At a national level, the group participates in the OSPT and the J.M. Burgers centre for fluid mechanics. The group is also actively participating in the research programme of FOM and the Dutch Polymer Institute.

*Quality*
The programme has a high relevance in engineering science and application. It builds upon an excellent tradition, which the programme director has been able to sustain and expand. The group belongs to the world leading groups in its fields. This is underlined by a very good publication record in the top Chemical Engineering journals and by a high citation impact of their publications. Over the years, the group has always been able to attract a well above average number of Dutch PhD students, which, after graduation, were highly demanded by industry.

*Productivity*
The number of publications in top Chemical Engineering journals has been remarkably high and constant over the last years. Considering the medium group size, the number of PhD students is fully appropriate, with a high success rate (75% finishing within 4 and 94% within 5 years). The numbers provided also show that the group has continuously and very successfully attracting both research funds and contracts.

*Relevance*
A particular strength of the group is its unbiased focus on issues in Chemical Reaction Engineering which at other places are considered traditional. This focus is and will remain of vital importance for the related (Dutch) industry, since other universities as well as industrial research laboratories tend to reduce their respective expertise or shift it to seemingly trendier topics.

*Viability*
The group is of about appropriate size with a well balanced age distribution and a flat hierarchy. Of particular strength are the excellent experimental facilities together with highly skilled laboratory staff, assets which also need to be actively cultivated in the future. The group appears to be well cross-linked with neighbour disciplines (notably membrane technology and catalysis) through the IMPACT research institute, which is at present headed by the director of the group. A continuing close cooperation with the Research Group 'Thermo-Chemical Conversion of Biomass' (which is not separately covered in this report) seems to be quite natural.

**Conclusion**
This is an internationally highly recognized group, continuing successfully the excellent Twente tradition in Chemical Reaction Engineering. It is recommended to keep and further strengthen its focus on areas which are at present being abandoned more and more by other universities, but remain of vital importance for the related industry. This requires continuous investments in the existing experimental facilities.

In order to do so, it could be necessary to seek for supportive measures through the industries concerned, since the Dutch funding situation seems to favour financial support in areas considered more 'fashionable' at present.

**Inorganic Materials Science**

| | | |
|---|---|---|
| Programme code: | UT 4 | |
| Programme director: | Prof. dr. ing. D.H.A. Blank | |
| Research staff 2007: | 18,24 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The research is focused on establishing a fundamental understanding of the relationship between composition, structure and solid-state physical and chemical properties of inorganic materials, especially oxides. Insights into these relationships enable to design new materials with improved and yet unknown properties that are of interest for fundamental studies as well as for industrial applications. With the possibility to design and construct artificial materials on demand, new opportunities become available for novel device concepts. The research of the group is strongly embedded in the research orientation on nano-materials and fabrication of MESA+, and the chair cooperates with several research groups in MESA+.

The current research themes are:

- Physical materials science & Artificial materials
- Chemical materials science & Nanostructured materials
- Interface science & Thin film technology
- Novel devices & Applications.

*Quality*
The group works at the international forefront of materials research on complex metal oxides. The director and the senior staff members each have their own expertise with a growing world-level recognition and impact. Those expertises are complementary and with a healthy overlap. The group activity is well orchestrated by the director. The international recognition of the group is confirmed by the strongly increasing number of citations in last few years.

*Productivity*
The group publishes in journals of high impact. It has a very good output of both international refereed academic publications and of PhD theses completed during the period 2001-2007.

*Relevance*
The group deals with highly relevant research topics at the forefront of functional-oxide science, aiming at nano-electronics and advanced sensor applications. It collaborates with equally competitive groups world-wide

*Viability*
The viability of the group stems from their excellent understanding and capacity in tailoring and controlling surfaces and interfaces. State-of-the-art equipment set up by the group and future development plans in this context are indeed essential to the future advancement.

**Conclusion**

The group has excelled in its research and produced several breakthroughs . Its capabilities and recognition are increasing. It can be expected to maintain excellence in fundamental research on surfaces and interfaces of functional oxides. In addition further extension of the research to other fields beyond nano-electronics, and development of know-how in tightly-controlled processing techniques suitable for large scale production, such as indeed planned, will enable the group to maintain its relevance and high standard in the future.

**Organic Materials Science**

| | | |
|---|---|---|
| Programme code: | UT 5 | |
| Programme director: | Prof. dr. G. J. Vancso | |
| Research staff 2007: | 10,65 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The general focus of research in the Materials Science and Technology of Polymers (MTP) group is on macromolecular nanotechnology and materials chemistry of nanostructured organic and organometallic macromolecular materials. MTP's mission is to devise and construct tools, establish approaches, and build molecular platforms that enable studies of macromolecular structure and behaviour from the nanometre length scale, bottom up, in a direct one-to-one control of the molecular objects. This knowledge is utilized to obtain advanced macromolecular materials and devices with enhanced or novel properties and functions for targeted applications.

*Quality*
This is a well-established, relatively small group that is remarkably active and focused on highly interesting current issues in forefronts of macromolecular surface and self-assembly nanotechnologies. The group has done pioneering seminal work in understanding the structure-molecular force relationship in H-bonded supramolecular assemblies by using AFM-based single molecule force spectroscopy. The great quality of their achievements is also illustrated by their work on nanolithography with organometallic polymers or on segmental dynamics in thin polymer films. This excellence results from a nice combination of talents in experimental techniques and judicious choice of highly relevant problems and questions. The results have been published in top journals and have an excellent citation record. The leader and its group are internationally very visible and active in collaborations with the leading teams throughout the world.

*Productivity*
Given its size, the programme has an excellent publication rate and a considerable number of PhD-students. The choice of journals is very well thought through and aims to reach different communities that might be interested in this research, which is often at the frontiers.

*Relevance*
The academic relevance of the work is very high. The group has been awarded prestigious and competitive grants. Recently the group has started to build a patent portfolio and develop contacts with industrial partners.

*Viability*
The group's high national and international visibility, very strong research record and sensible scientific plans bode well for the future. However, to secure future developments there is a need for an additional position in the group in order to broaden the available expertise.

**Conclusion**
The group has produced several remarkable findings at the forefront of international research in macromolecular nanotechnology and maintained an excellent productivity over the assessment period. The research programme is coherent and strategically well designed.

**Separation Technology**

| | | |
|---|---|---|
| Programme code: | UT 6 | |
| Programme director: | Prof. dr. ir. M. Wessling | |
| Research staff 2007: | 28,79 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The programme deals with molecular separations based on technical membranes. Integrating various disciplines across length scales from molecular manipulation to process development, should result in viable technical solutions to challenging separations of molecular mixtures.

The group participates in three Research Institutes:

- BMTi, where the group is engaged in membrane research related to tissue engineering, drug delivery and functional membranes for blood purification and bio-separations
- MESA+, where the group participates in nano- and micromodification of membranes and membrane surfaces
- IMPACT, in contact with which the group produces membranes and provides membrane processes for a wide range of industrial applications.

*Quality*
The group builds upon an excellent tradition. The present director has even been able to expand the reputation remarkably and to interconnect the group efficiently with many neighbouring disciplines into a strong scientific UT network. In addition, the group is closely connected with the European Membrane Institute (EMI), a legally independent and self-supporting institution; in which application-oriented and often confidential membrane research is conducted with industrial partners. This broad basis has put the group into a world-leading position in several important areas of membrane science and application.

*Productivity*
The group has a very good publication record and is publishing its research in a wide range of high ranking scientific journals and obtains high citation rates. Considering the size of the permanent staff, the number of PhD students is high, with a large majority finishing within four years. The group has been most successful in attracting both research funds and major contracts on a continuous and regular basis.

*Relevance*
The particular strength of the group lies in its broad interdisciplinary orientation which allows it to provide its expertise in areas as different as tissue engineering, water purification and chemical reaction engineering and to develop new insights and expertise together with experts from polymer-, material- and nano-science. This renders the research highly valuable.

*Viability*
The success of the group is closely connected with the exceptional ability of its director to build interdisciplinary networks and to expand the work into new, highly attractive application areas. The danger to overstretch its possibilities by expanding into too many new areas has in the past been successfully avoided by also deliberately abandoning certain research directions.

**Conclusion**
The group represents a most visible and highly attractive research field, strongly relying on the drive and the vision of its present director. Considering the reassessment of actively pursued research directions it might be useful to re-establish expertise in molecular modelling/dynamics or to closely cooperate closely with competent partners in this field.

**Supramolecular Engineering**

| | | |
|---|---|---|
| Programme code: | UT 7 | |
| Programme director: | Prof. dr. ir. J. Huskens (since Sept 2005), Prof. dr. ir. D.N. Reinhoudt (until Sept 2007) | |
| Research staff 2007: | 20,7 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The research concerns the chemistry that deals with noncovalent interactions, and covers the structures and functions of entities held together by multiple, weak, reversible interactions. A major goal is to transfer the principles that govern the functions of living systems to the artificial world of materials with designed structures and functions.

*Quality*
The high quality of this research group (SMCT) is internationally renowned for an original and high impact contribution to supramolecular chemistry, nanotechnology and multimodal imaging systems that stretch from NMR to fluorescent spectroscopy. The past director, who retired in 2007, is a highly prominent scientist, with a clear and ambitious vision in research and education, as attested by (i) a staff of young, very promising if not already prominent scientists, (ii) an impressive impact of his publications, (iii) a privileged funding that consists of 70% direct funding and 24% research funds, (iv) prestigious awards, grants, memberships, and international collaborations via projects and networks of excellence, (v) external outreach of graduates in prestigious laboratories and industries. The clear vision of the present director, who joined the group in 2005, and a recent appointment broadening the scope of the research, promises a continuation of the excellence of the group.

*Productivity*
A very demanding publication strategy accounts for the best bibliometric data in the Chemical Engineering discipline, with a very high crown indicator typical of a very strong group. The high productivity is consistent with a large number of PhD theses with respect to the size of the staff.

*Relevance*
The mission is at the front lines of science, with the purpose to contribute to the development of up-to-date nanotechnologies. In addition to scientific relevance, the core position of the group in the MESA+ Institute for Nanotechnology is evidence of the industrial relevance of its activities.

*Viability*
In 2005, the original SMCT group was divided into two independent groups: (i) the current SMCT group, with the full professor position opened at the departure of the former director in 2007, and now dedicated to bio-imaging, and (ii) the new Molecular Nanofabrication group (biomolecular assembly on surfaces), headed by a former associate professor. Within the framework of the 3TU federation, a third group started very recently (2009) with a focus

on biomolecular nanotechnology. The general programme is thus typically oriented towards bionanotechnology. Although the potential of this restructured research programme is high, the Committee wants to draw attention on the critical importance of the management of the transition phase and the need of coherence between the senior researchers for an international top level in science and education to be maintained.

**Conclusion**

The internationally renowned group formerly headed by Prof. Reinhoudt, is at a turning point in its life. The splitting into three subgroups must be negotiated with great concern of coherence, complementarities and innovation for the international visibility of the whole programme to remain very high.

# 5. Eindhoven University of Technology

## 5.1. Department of Chemical Engineering and Chemistry

**Introduction**
The department of Chemical Engineering and Chemistry (ST) is one of the nine departments of Eindhoven University of Technology (TUE). The department was established in 1957. The profile of the department is a balanced mixture of chemistry, materials science and technology, and process engineering sciences. The research has developed into four areas: (i) Macromolecular Chemistry and Molecular Materials, (ii) Polymers and Composites, (iii) Process Engineering and (iv) Catalysis. The current staff numbers at the department are 420 fte, including 13 full professors, 16 part-time professors from industry and technical institutes, 21 associate professors, 21 assistant professors, and 96 technical and administrative support staff. There are approximately 250 engineering (BSc and MSc) students, 160 PhD students, 22 PDEng students, and 70 post-doctoral fellows. The department's annual budget is approximately € 30 million, about 50% of which is obtained from external funding.

**Leadership**
The department board, appointed by the university board, consists of the dean, the vice-dean, and the managing director. Two advisors, the director of education and a student representative also attend board meetings. The dean is ultimately accountable for the entire management, while the managing director is responsible for matters concerning personnel and organization, financial administration, services and housing. The research group leaders operate to a large extent as autonomous 'entrepreneurs' within the framework and boundaries set by the department board; they fully control their group's finances.

**Mission & Goals**
The mission of the department of Chemical Engineering and Chemistry is:
'To perform research, aiming at excellence, in selected areas of chemical engineering and chemistry which are relevant for future societal needs and where the research vectors are determined by the vision of individual high-profile members of the department rather than by external funding agencies.'

**Strategy & Policy**
The department has adopted a new research strategy in November 2008. The strategy is based on two main considerations:

- Continuation and strengthening of the present research focal points in supramolecular chemistry, polymer chemistry & technology, process engineering, and catalysis. These focal points will be brought together in the four research clusters: Macro-Organic Chemistry and Molecular Materials, Polymer Chemistry and Materials, Reaction and Process Intensification, and Catalysis and Energy Conversion Processes.
- Renewal and rejuvenation in the area of process engineering. Due to the retirement of staff and the leaving of staff for other positions in the period 2007-2011, the total number of staff in the area of process engineering will drop with eight fte, including two group leaders at the full professor level and six assistant and associate professors. Therefore, two new chairs will be positioned in the research cluster Reaction and Process intensification, including two fte scientific staff per chair, six fte in total. These chairs should address the fields of Chemical Process Intensification and Microfluidic Chemistry and Technology.

In total, three new chairs are proposed: two in the cluster Reaction and Process Intensification and one in the cluster Catalysis and Energy Conversion Processes.

**Evaluative remarks about Leadership, Mission & Goals and Strategy & Policy**
The Committee wants to state explicitly that, generally speaking, this department handles both scientifically and societal very relevant research topics in the area of modern chemical technology in a focussed and efficient way. The department has without any doubt reached an international top position.

The organization of the department is highly structured and in principle allows a balance between bottom-up and top-down decision-making. Although coherence and focus on main-stream activities is to a large extent guaranteed in this fashion, the Committee has the feeling that the bottom-up component could receive more specific attention and could further be strengthened, primarily through more explicit stimulation of innovative small-scale initiatives and of interdisciplinary interactions, thus allowing the individual players to adapt to sudden new promising developments and to implement some research activity on selected high-risk approaches. This should allow individuals to implement their vision more rapidly and in a more creative way than exclusively in the frame of large externally defined and funded programmes.

The determination of '*research vectors by the vision of high-profile members rather than by external funding agencies*' is explicitly present in the mission statement. Taking into account reactions of individuals during the site-visit, the Committee has the impression that the structure, which seems rather heavy on-paper, is handled with the necessary flexibility and suppleness. It invites the board to continue along the same lines.

The Committee has appreciated the continuous efforts of the department to keep standards high and research topics timely and focussed. As a result of a VSNU assessment (2001), a mid-term self-assessment (2005) and the presentation of a blueprint for reorientation (2008), the central research topics are continuously renewed and strengthened and adapted to societal relevance, while at the same time retaining focus. At the same time, it seems to the Committee that the proposed measures to do so efficiently, viz. via the proposal of three new chairs, are adequate enough. More specifically, the request to bring catalysis back to its originally strong numerical top position has for the major part already been taken care of. With the new successor of Prof. van Santen, guarantees seem to be present to successfully finish this process. In the same context, the Committee has during the on-site visit devoted ample time to the succession of Prof. Lemstra and the resulting structural changes. After considering the proposal of the department concerning the departmental restructuring related to this retirement, and a few internally defined alternative options of its own, the Committee fully supports the proposal advanced by the department. The Committee is aware of the risk, apparently shared by the university authorities, of substituting the Lemstra approach, viz. cooperation along the chain of knowledge in the area of polymeric materials, by that of a too fundamental bio-nano profile. The Committee, therefore, wants to stress that the department in its search for candidates for vacant positions, should remain alert for the appearance on the international scheme of 'rejuvenated' versions of Profs. Lemstra or Van Santen. Hiring them should remain a priority.

The Committee appreciates the department's initiative to invite individual staff members to write career plans and discuss their integration in the department's general policy. The Committee encourages the department to continue along these lines and to use this information as part of its policy making strategy.

As far as international benchmarking of the individual groups is concerned, reference is invariably made to several international top-groups active in restricted areas on specific and narrow topics. It is clear that on the average the approach to aspects of 'chemical technology/engineering' is significantly broader at TUE compared to that of similar departments.

Considering the 3TU Centre of Excellence initiative, the Committee has the feeling that this mainly helps sponsoring new staff-positions. It remains unclear whether it was ever meant to strengthen collaboration among the 3TU's involved in terms of sharing topics, staff positions and collaboration beyond the administrative and coordinative level. The Committee feels that this could be a handle to enhance ,strengthen and expand collaboration among the institutes. Regarding the 'TOP School on Catalysis' initiative, the Committee has the feeling that this has created the required environment to internally stimulate an interdisciplinary approach to catalysis and has been very beneficial for the groups involved in assuring high international visibility.

**Resources**
The sizes of the three new research clusters in terms of full-time equivalent of scientific staff (professor, assistant- and associate professor level) are as follows: 8 fte (Macro-Organic Chemistry and Molecular Materials), 12 fte (Polymer Chemistry and Materials), 16 fte (Reaction and Process Intensification), 9 fte (Catalysis and Energy Conversion Processes), giving a total of 45 fte scientific staff. This is the maximum number of staff that can be accommodated in terms of the department's direct funding. The new chair Inorganic Materials Chemistry is funded for five years from the 3TU Centre of Excellence. Additional funding for other chairs will be obtained from the Sectorplan, which is presently being implemented by the Dutch government to support chemistry and physics departments in the Netherlands. Further extension of the department's research profile and focus into new areas, such as for example Chemical Biology, Biochemical Engineering, Technical Life Sciences, or Biomedical Engineering, will be discussed in a later stage.

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **total** |
|---|---|---|---|---|---|---|---|---|
| Full professors | 6,4 | 5,3 | 5,4 | 5,9 | 5,9 | 6,84 | 7,5 | 43,2 |
| Associate professors | 6,6 | 6,0 | 5,3 | 4,9 | 4,6 | 4,49 | 4,4 | 36,2 |
| Assistant professors | 6,5 | 6,5 | 7,3 | 8,5 | 9,8 | 9,12 | 10,0 | 57,6 |
| Other tenured staff | 0,1 | 0,0 | 0,1 | 0,2 | 0,2 | 0,2 | 0,2 | 1 |
| Total tenured staff * | 19,5 | 17,8 | 18,1 | 19,4 | 20,5 | 20,7 | 22,0 | 138,0 |
| **Total tenured staff ** ** | **21,5** | **19,7** | **20,0** | **21,5** | **25,0** | **24,8** | **26,1** | **158,6** |
| | | | | | | | | |
| PhD students | 87,6 | 94,7 | 95,7 | 94,5 | 105,3 | 108,7 | 111,5 | 698 |
| Other non-tenured staff | 42,8 | 44,6 | 45,4 | 49,3 | 46,0 | 46,3 | 49,8 | 324,2 |
| Total non-tenured staff | 130,4 | 139,3 | 141,1 | 143,8 | 151,3 | 155 | 161,3 | 1022,2 |
| **Total research staff** | **156,4** | **162,7** | **169,3** | **172,5** | **179** | **182,1** | **190,2** | **1212,2** |

Table 5.1. Staff at department level (in research fte).
*) calculated from the figures per programme
**) figures provided in the general part of the self-evaluation report

| | factor of research |
|---|---|
| Full professors, associate professors and assistant professors | 50% |
| Postdoctoral associates | 90% |
| PhD students | 75% |

Table 5.2. Factor for converting fte to research fte.

**Evaluative remarks about Resources**

*[The figures concerning the total tenured staff provided in the general part of the self-assessment report differ slightly from those obtained by adding up the figures of the individual programmes (Table 5.1.).]*

The data in table 5.1. point to a steady growth of total tenured staff, number of PhD students and post-docs (= other non tenured staff) over the period covered by the assessment. While this increase over the whole period is about 18% for the total tenured staff, it amounts to 20 and 14% for the number of PhD's and post-docs, respectively. The Committee feels that the department should keep in mind this less than proportional growth at the level of the (international) post-docs compared to that of staff and PhD's, and pursue attracting international post-docs with specific expertise. When the 2007 ratio of PhD students per total tenured staff member, viz. 4.3, is considered, the Committee feels that there is still room for further enhancement of the research load of the staff as far as PhD coaching is considered. A positive effect on the quantitative research output and as a result on the research efficiency is to be expected. As future direct funding will allow only staff 'rejuvenation' (10 % decrease from 2009 onwards combined with an increase via the 'Sectorplan' after 2011), modest further growth in absolute output has to be assured this way. Consequently the department should show its creativity as far as the development of an attractive and specific hiring policy of excellent PhD's and post-docs is concerned. Indeed, the present generation of PhDs, via their representatives, has expressed in the interview with the Committee during the site-visit, its appreciation for the ability not only to do creative research in state-of-the-art equipped laboratories, but also to deploy the necessary social activity. Such elements could form the basis of a continued search policy for post-docs and PhDs.

42% of the staff falls within the age-range of 41 to 50, and should thus be in a very productive period of their careers. 33% of the staff is even younger than this, which provides significant growth potential. Only 25% of the tenured staff has an age range between 51 and 60. It is clear that the rejuvenation policy has been successfully implemented and an active and creative staff should be on board.

**Funding Policies**

The department's budget allocation system has been designed to meet the financially autonomous positions of the research groups. The entrepreneurship of individual group leaders is strengthened by the incentives built into the system of allocation of the 'direct' funding via the university, all additional funding going entirely to the group that earned it. This allocation system is one of the major management tools used by the department board. It operates as follows: the total annual budget of direct funding, as made available to the department by the university, is split up into three categories:

- funds needed for educational support and organization, and other overhead;
- discretionary funds for new initiatives by the department board;
- funds for education and research.

The board decides on the amounts needed for the first two categories. What remains is distributed among the research groups based on their efforts spent on education and on research. For the latter the criteria are the (three-year average) number of PhD theses produced, and the (three-year) average of external funding. All factors are relative to the total of all groups; this 'zero-sum game' is intended to provide a strong incentive for high performance in all areas that are relevant for a university group.

Except for some modest discretionary funding by the department board, external grants presently supply all running costs of PhD salaries, consumables and capital investment in apparatus and equipment. A portion of the grants originate from national funding agencies like the Netherlands Organization for Scientific Research (NWO), the Dutch Technology Foundation (STW), and others, on a basis of project proposals in an open competition with the chemical engineering and chemistry community in the Netherlands. The other part is financed through industrial contracts and the European Union. This provides a balance between the need for scientific excellence and the push for the valorisation of the scientific results – an important incentive for a department of chemical engineering and chemistry.

| | **2002** | | **2003** | | **2004** | | **2005** | | **2006** | | **2007** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Funding** | % | k€ | % | k€ | % | k€ | % | k€ | % | k€ | % | k€ |
| Direct Funding | 58 | 14,4 | 56 | 14,7 | 56 | 15,1 | 52 | 14,9 | 51 | 15,1 | 53 | 15,9 |
| Research Funds | 14 | 3,5 | 9 | 2,3 | 11 | 3 | 14 | 3,9 | 17 | 5,2 | 12 | 3,8 |
| Contracts | 28 | 7,1 | 35 | 9 | 33 | 8,9 | 34 | 9,6 | 32 | 9,4 | 35 | 10,5 |
| **Total Funding** | **100** | **25** | **100** | **26** | **100** | **27** | **100** | **28,4** | **100** | **29,7** | **100** | **30,2** |
| **Expenditure** | | | | | | | | | | | | |
| Personnel Costs | 65 | 16 | 67 | 17,8 | 71 | 18,9 | 69 | 19,2 | 64 | 18,9 | 67 | 20 |
| Other Costs | 35 | 8,6 | 33 | 8,6 | 29 | 7,8 | 31 | 8,7 | 36 | 10,7 | 33 | 9,9 |
| **Total expenditure** | **100** | **24,6** | **100** | **26,4** | **100** | **26,7** | **100** | **27,9** | **100** | **29,6** | **100** | **29,9** |

Table 5.3. Funding and expenditure of the Institute

Direct government funding has remained more or less stable during the past six years, while funding from industry and the European Union has increased substantially. From 2009 onwards, this direct government funding will decrease by approximately 10%, mainly as a consequence of external policy developments. From 2011 onwards, an increase is again expected, resulting from the national Sectorplan for chemistry and physics.

**Evaluative remarks about Funding**

Compared to many other European countries the direct government funding seems to be excellent. The Committee believes that the expected 10% decrease of this funding between 2009 and 2011 followed by an enhancement via the Sectorplan should not be visible as a dip in the department's output and could be compensated by an enhanced productivity of the staff (see remarks on Resources). External funding is high and typical for a well-functioning department with strong emphasis on societal relevance. When going through the list of partners involved in bilateral collaborations with 'entrepreneurs' from the department, it is striking that the majority of them consists of companies with roots in The Netherlands. Given the European context in this area, growth has not reached its limits. The relatively large funding by DPI in some areas of the department might cause concern.

The Committee remarks that the costs of staff is significantly below 70%, compared to other costs and allows sufficient flexibility in terms of policy changes.

According to remarks by individuals during the site-visit, the Committee feels that the level of discretionary funding (redistribution) by the department board should be enhanced, allowing rapid implementation of new creative ideas by individuals.

**Facilities**
The self-evaluation report states that the research groups have access to an excellent technical infrastructure. In the sophisticated (high-tech) laboratories all groups have or share the equipment that is needed for the research work. Special equipment that cannot be purchased is manufactured by the Central Workshop (Gemeenschappelijke Technische Dienst, GTD) at the TU/e. Further investments are continuously being made for launching new initiatives in and for keeping up the state-of-the-art quality of the equipment. The department is the minor occupant of the building Matrix. This building currently houses large process equipment, meeting rooms and educational rooms for project work.

**Evaluative remarks about Facilities**
The high quality research output, for example, indicates that all necessary state-of-the-art equipment is available. This was confirmed during the interview with the PhD students.
Given the significant number of publications in which at least two research groups of the department are involved (on the average over one-third of the output), it follows that in general the groups interact rather significantly, also at the level of sharing advanced high-tech equipment.

**Academic Reputation**
The impact of the department's papers in the 10-year period 1997-2006 compared to the average citation rate of the department's journal set, is significantly above the average citation rate of this journal set (CPPex/JCSm = 1.31). Also the impact of the department's papers compared to the world citation average in the subfields in which the department is active, is significantly above the world average (CPPex/FCSm = 2.09). A trend analysis shows that the impact of the department's papers is consistently very high over the years, and varies between 2.00 and 2.33 for overlapping periods of four years in the period 1997–2006.

**Evaluative remarks about Academic Reputation**
On a qualitative basis, the majority of groups are internationally recognised players in their respective domains. When a ranking of all visited groups is considered based on the scores from the bibliometric study, three groups receive the qualification *excellent* in every respect. Another two also show excellent results, though sometimes they are susceptible to further improvement with respect to certain aspects. Two groups score below the department's average.

Generally, a very significant number of the department's publications can be found in the top journals of the respective disciplines and frequently appear in journals covering several disciplines. Invariably, the citations of the department's publications exceed the average citation numbers of the respective journals. The impact of the papers is also significantly better than the world's average in the respective domains.

Occasionally, individuals in the department have received international or European awards. Recognition via national awards has been abundant.

**Societal Relevance**
Continuous collaboration with major industries is both a welcome and a necessary source of inspiration for the research conducted at the department. The output of the research is shared with society at large mainly through a large number of joint projects with industry. Strong ties have been developed with the major European (petro-)chemical, high-tech electronic, and food industries that are located within a radius of 150 kilometres, such as DSM, Philips, Unilever, ASML, Bayer, Shell, Sabic/Sabic-IP, Dow. The department is also actively involved in the extensive educational outreach effort of the university.

**Evaluative remarks about Societal Relevance**
Most of the groups show intensive interaction with industrial partners via collaborative efforts (see also sub *funding*). The output of the department in terms of assigned patents is impressive, while continuous attention seems to be present for valorisation of own findings through spin-out initiatives. The Committee has noted, however, that most of the preferred industrial partners seem to have their headquarters rather locally. It is striking that intense interactions between these partners and the department has occurred in terms of hiring highly qualified engineers and scientists and attraction of specific industrial expertise by means of recruiting (mostly part-time) professors.

**Balance of Strengths & Weaknesses**
The institute has provided a short analysis of strengths and weaknesses, and of the perspectives and expectations. The main points are:

*Strengths:*
- strong ties with the major European (petro-)chemical, high-tech electronic, and food industries
- strong research profile in various areas such as Catalysis, Macromolecular Sciences, Polymer Technology, and Process Engineering.

*Weaknesses:*
- low numbers of enrolment in the Bachelor and Master programmes.

*Opportunities:*
- the retirement around 2010 of three senior professors offers the opportunity to restructure the department with new research vectors in close balance between 'science beyond the current horizon' and applied science with direct societal relevance for the current industrial partners.

*Threats:*
- attracting new staff members at professor and staff level will become increasingly difficult in view of competition with jobs in industry and ample vacancies at chemical engineering departments in Europe.

**Evaluative remarks about Strengths and Weaknesses**
The Committee recognises that the present department is top level in a very broad area of societal relevant scientific activities. It has continuously adapted its activities to new emerging trends in these areas and has tried to keep the age distribution of the staff adequate by -timely substitutions and appointments of high quality individuals. It has been very successful in maintaining its high standards and securing its output. Most of the individuals are internationally very visible indeed.

The policy followed by the department to come up with replacements of senior professors was promising (in case of Prof. Van Santen) or offers adequate solutions (in case of Prof. Lemstra).

In terms of enrolment of master students, the department should actively pursue how the number of students of varied backgrounds might be increased. The same is true for hiring a higher number of very good PhD students, given the available coaching potential.

The threat formulated by the department, facing an increasing international academic and industrial competition for excellent people, is appreciated by the Committee. However, given its presently accepted international high reputation, the excellent research environment (as confirmed by the current PhD students), and the expertise of many individuals in timely research areas, the department should be in an advantageous condition to face this international competition. The Committee agrees that the practical implementation of these elements require daily attention.

## 5.2. Assessment per programme: Dept of Chemical Engineering and Chemistry

The Committee assessed the following programmes of the Department of Chemical Engineering and Chemistry:

| | Quality | Productivity | Relevance | Viability |
|---|---|---|---|---|
| **Research programmes** | | | | |
| TUE 1 Macro-organic Chemistry | 5 | 5 | 5 | 5 |
| TUE 2 Molecular Materials and Nanosystems | 5 | 5 | 5 | 5 |
| TUE 3 Supramolecular Polymer Chemistry | 5 | 5 | 5 | 4 |
| TUE 4 Macromolecular Chemistry and Nanoscience | NA | NA | NA | NA |
| TUE 5 Polymer Technology | 4 | 5 | 5 | NA |
| TUE 6 Polymer Chemistry | 4 | 5 | 4 | 4 |
| TUE 7 Functional Polymer Colloids via Radical Polymerization | 4 | 5 | 4 | 4 |
| TUE 8 Materials and Interface Chemistry | 4 | 5 | 4 | 4 |
| TUE 9 Chemical Reactor Engineering | 5 | 5 | 5 | 4 |
| TUE 10 Process Systems Engineering | 3 | NA | 3 | 3 |
| TUE 11 Separations and Transport Phenomena | 3 | 2 | 3 | NA |
| TUE 12 Molecular Heterogeneous Catalysis | 5 | 4 | 5 | 4 |
| TUE 13 Homogeneous Catalysis & Coordination Chemistry | 5 | 4 | 5 | 5 |
| TUE 14 Physical Chemistry of Surfaces | 4 | 4 | 4 | 4 |

The detailed assessment per programme follows in the next section of this report.

**Macro-organic Chemistry**

| | | |
|---|---|---|
| Programme code: | TUE 1 | |
| Programme director: | Prof. dr. E.W. Meijer | |
| Research staff 2007: | 24,25 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The research is based on three sub-disciplines: 1) biochemistry and chemical biology; 2) macromolecular and organic chemistry; and 3) nanoscience and nanotechnology. With the design, synthesis and characterization of supramolecular multi-component objects of both biological and synthetic fragments in the 3-10 nanometre regimes, the aim is to study the structure and dynamics of well-defined functional objects that will lead to new applications.

The focus is on three research topics:

- Supramolecular π-conjugated assemblies.
- Supramolecular polymers, helical aggregates and (bio)materials.
- Supramolecular biomedical chemistry.

*Quality*
The group has a world leading position in the design and synthesis of (macro)molecular precursors of functional supramolecular objects according to advanced non-covalent synthetic schemes. This extensive expertise is completed by a high capacity in characterization and applications either in life sciences or in materials. The successful integration of all the expertises in 'one ensemble', whose growth is limited by the 'walls' of a departmental structure, has led to an organization deprived of artificial limitations: the TU/e Institute for Complex Molecular Systems (2008) in which the Macro-organic Chemistry group has a core position.

The programme director is a very prominent scientist, who is ranked in the top 100 of most cited chemists worldwide (since 2003) and is highly involved in national and international organizations and collaborations

*Productivity*
In addition to numerous patent applications (2002-2007) filed by industrial partners, all the bibliometric indicators are high consistent with the high quality and productivity of the research despite of the broad field of activities. For instance, the crown indicator is 3.70+, which ranks the group at the level of top groups in the best US universities.

*Relevance*
The highly relevant multidisciplinary knowledge and experience of the group are combined with socially relevant topics, such as energy, health and environment. A strong relationship between research and education of young students and researchers must be emphasized, and an active involvement in the outreach of science to the public at large, as well. Contacts with the industrial world are vivid and well-organized (via 2 start-up companies), not only for iden-

tifying fundamental issues on technologically relevant topics but also for commercializing the proprietary technology platform of supramolecular (bio)polymers.

*Viability*
Viability is not a concern for a group which extends its vision and expertise beyond the frontiers of several departments, and generates enthusiasm and excitement in spite of a very demanding involvement.

**Conclusion**
This worldwide renowned group has a unique capacity to grow while passing the institutional barriers and maintaining if not increasing, the scientific and societal impact of its activities.

**Molecular Materials and Nanosystems**

| | | |
|---|---|---|
| Programme code: | TUE 2 | |
| Programme director: | Prof. dr. ir. R.A.J. Janssen | |
| Research staff 2007: | 21,11 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The group aims at a coherent scientific research programme on the chemistry, physics and materials science of functional nanostructured molecular, polymer and hybrid materials, and nanosystems that may find application in photonic and electronic technologies.

The mission is: the creation, organization, characterization and understanding of the functioning of molecular materials and nanostructures that can be assembled into larger (complex) architectures or devices and that exhibit novel physical properties and phenomena.

*Quality*
An interdepartmental research group with expertise spanning from synthesis through optical spectroscopy and scanning probe techniques to the fabrication and testing of final device, this unit is successful in integrating the activities of a large number of chemists, chemical engineers and physicists towards the production of a high quality, relevant and important research, contributing significantly to their field.. The quality of the programme and the prominence of the director are testified by an increasing number of citations resulting in a high and steadily increasing crown indicator.

*Productivity*
A very high number of publications, approximately half of them in the highest impact journals, a number of patents and a high number of PhD students indicate an excellent output.

*Relevance*
The programme contains application-stimulated research spanning from the molecule to the material-system and from the basic phenomena to the device. Numerous collaborations with academic institutions and with industries as well as numerous invitations for lectures in conferences, tutorials and seminars testify to the relevance of the research performed by the group.

*Viability*
The research area is highly viable, the field being still in an expanding stage. The programme is also coherent with the defined priorities of TU/e. High external input of finances for research originate in a balanced way from agencies supporting fundamental science, agencies supporting application oriented work , and industries, and cover costs of most of the non-permanent staff. Judging from the successful history of the director in attracting research funds, the future potential is bright.

**Conclusion**
This is a solid group with excellent output. A path for a yet further excellence would be to target entirely novel concepts and broaden fundamental innovations. Based on the prominence of the group as testified by all the indicators, the future plans outlined by the director are fully supported by the assessment Committee.

**Supramolecular Polymer Chemistry**

| | | |
|---|---|---|
| Programme code: | TUE 3 | |
| Programme director: | Prof. dr. R.P. Sijbesma | |
| Research staff 2007: | 5,3 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The group aims to design, synthesize and characterize self assembled polymeric materials with functionality derived from structuring at the nanometre length scale, or from responsivity to molecular or mechanical stimuli. This mission reflects the two research areas defined within the group: (i) Nanostructured materials based on hydrogen bonded self-assembly and (ii) smart responsive materials. In the first area, hydrogen bonding is used as a well-defined non-covalent interaction to structure materials at the nanometre length scale. In the second research area, molecular recognition or mechanical stimuli induce changes in the properties of polymeric materials.

*Quality*
This is a small new research group built by prof. Sijbesma, a former member of the Macroorganic Chemistry programme, who continues his work on hydrogen-bonded supramolecular polymers and also develops new themes aiming at design and synthesis of mechano- and chemoresponsive polymer and supramolecular materials. In all these areas this is a world leading group with absolutely outstanding publication and citation record in the most prestigious journals. The impact of the work on supramolecular self-assembly by self-complementary hydrogen bonds is tremendous. Also the work on mechanochemistry of coordination polymers is first class and illustrates well both the scientific talent and good taste of the group leader for opening original and relevant research directions.

*Productivity*
The academic productivity of this group is excellent and the publication and citation numbers speak for themselves. The number of PhDs produced could eventually be raised provided that there is adequate staffing.

*Relevance*
The problems addressed by the group are central to the current development and future of materials based on supramolecular chemistry. The current projects, in particular those concerning supramolecular mechanochemistry or self-repair could open new technological avenues.

*Viability*
Given the group leader's outstanding academic record and the excellent environment for functional material science at TU/e, there is every reason to believe that the group can remain a leader in the field of supramolecular and self-assembled polymers. The group is relatively small and desires not only to focus on fundamental research, but also to move towards more application-oriented projects. Such an evolution is sensible and future projects concerning functional materials sound very attractive. However, in order to be competitive and successful the group needs reinforcement.

**Conclusion**
This programme created by a very motivated and talented scientist emerges as a leading effort in the very active and attractive field of the use of molecular recognition for bottom-up synthesis of new materials. The academic reputation of the group is excellent and the ambition of the programme to expand towards more applied projects is to be encouraged.

**Macromolecular Chemistry and Nanoscience**

| | | |
|---|---|---|
| Programme code: | TUE 4 | |
| Programme director: | Prof. dr. U.S. Schubert | |
| Research staff 2007: | 20,95 | |
| Assessments: | Quality: | NA |
| | Productivity: | NA |
| | Relevance: | NA |
| | Viability: | NA |

The mission of the laboratory is to combine synthesis and advanced characterization of self organizing functional materials and tailor-made complex macromolecules with selective deposition and micro-/nano-structuring methods of substrates. The ultimate aim is to approximate the perfection of natural systems both with respect to morphology and function, using synthetic systems. To be able to systematically vary the molecular parameters of the (supra) macromolecules and to identify quantitative structure-property relationships, parallel (microwave-assisted) synthesizer and combinatorial approaches in combination with high throughput screening methods have been incorporated into the scientific programme.

Since the director left TU/e and no interview with representatives of this programme was scheduled, this programme was not rated.

**Polymer Technology**

| | | |
|---|---|---|
| Programme code: | TUE 5 | |
| Programme directors: | Prof. P.J. Lemstra & Prof. D.J. Broer | |
| Research staff 2007: | 14,8 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | NA |

*Short description*
The group aims to create and understand polymer structures in order to develop advanced polymer systems and devices (at demonstrator level) in a chain-of-knowledge approach. The programme covers three research themes: Plastics and Composites, Functional Polymers, and Bio-based and Bio-inspired Polymers. These themes utilize the same knowledge base involving thermodynamics, chemistry and physics.

*Quality*
The programme has gained a rather unique and well deserved reputation as a leading group in polymer physics and technology and was highly visible both in industry and academia. The group's remarkable achievements are reflected in very successful collaborations with a wide network of industries, the patent portfolio, as well as impressive start-up spin-off activities. Research, both in traditional and emerging areas of polymer science, has been highly innovative. Work on enhancing life-time of artificial hips and knees, on panel displays, membranes, solar energy collectors and sensors are good examples. Also, some fundamental work of the group was of top quality and attracted a lot of attention. The concept of all-polymer composites, the papers on lowering the viscosity of polymer melts via dispersing of nano-sized silica and on heterogeneity in melts of crystallisable polymers could, for example, serve as wonderful illustrations of how industrially relevant research can bring new remarkable insight into polymer science.

*Productivity*
The productivity of the group as measured by the number of publications, PhD theses, the number of filed patents and the success in creating quite a number of spin-off activities is excellent.

*Relevance*
The group has worked on scientifically challenging projects of direct relevance to current and future industrial needs and has been able to implement a global innovative approach. The fruitful collaboration with not only big industrial companies which traditionally collaborate with universities, but also with small and medium size enterprises is absolutely impressive.

*Viability*
Professor Lemstra, the head of the programme, will retire and the programme as such will be stopped.

**Conclusion**

The programme has been essential for placing Eindhoven as an internationally leading centre of polymer research. It fostered a unique global approach where industrially relevant questions encouraged very innovative multidisciplinary fundamental science. The programme has been crucial to establish high quality education of students and researchers in the field. It is regrettable that this programme that combines traditional and emerging (functional) polymer materials fields and a unique application chain of knowledge oriented philosophy, is now being terminated. The departmental proposal to split the group and reinforce the Polymer Chemistry programme on the one hand and introduce some expertise in functional materials to develop application oriented projects in Supramolecular Polymer Chemistry on the other could be a very sensible alternative in this situation.

**Polymer Chemistry**

| | | |
|---|---|---|
| Programme code: | TUE 6 | |
| Programme director: | Prof. dr. C.E. Koning | |
| Research staff 2007: | 16, 74 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 5 |
| | Relevance: | 4 |
| | Viability: | 4 |

*Short description*
The programme is concentrated on the synthesis of functional, bio-related and performance polymer systems. A variety of polymerization mechanisms and techniques is utilized, and optimized via detailed mechanistic studies. The ultimate goals of the group are to develop increasingly complex and demanding materials for advanced applications and to actively pursue sustainable resources and technologies through the use of Nature-inspired concepts and tools.

*Quality*
When the former leader of the Polymer Chemistry (PC) group retired in 2000, the research activities – radical polymerisation and emulsion technology – were pursued independently by Prof. C.E. Koning, the new leader of the PC group, and Prof. A.M. van Herk, who headed a Functional Polymer Colloids and Radical Polymerization group. Prof. Koning extended the research effort to two additional polymerisation fields, i.e. step-growth polymerisation, which is an industrially relevant field with a lack of experts, and all types of polymerisation catalysis (homogeneous, heterogeneous and enzymatic). This ambitious programme led to significant contributions to the field of traditional polymerisation mechanisms and related materials. Breakthroughs in processes related to solid-state postcondensation, nanocomposite production and enzymatic polymerisation increased significantly the international visibility of the group.

*Productivity*
As a whole, the productivity is excellent as assessed by the high quality of the papers and, after normalisation for group size, by a high number of patents and defended PhD theses.

*Relevance*
The programme is conducted in close relationship with industry, which is the major sponsor of the research, mainly via the Dutch Polymer Institute (DTI). As a result, research contracts constitute at least 80% of the total funding. The PC group thus provides industry with the scientific and technological support that it needs, which is a mission expected from a University of Technology. This dual scientific and technical relevance of the research projects is emphasized by a good balance between patenting activity and scientific publication strategy, both of which are considered to be very good (cf. Supra).

*Viability*
It is very challenging to push the research effort in depth when the research front is broad and the staff is limited. This possible threat for the future might be solved by the envisioned restructuring of the groups that constitute the Polymers and Composites sub-discipline. This

reorganization would strongly consolidate the PC group by combining the groups of Prof. Van Herk and Dr. Goossens (now part of the Polymer Technology group). This restructuring would not only be beneficial to the long-term viability of a very pertinent research on the main industrial polymerisation mechanisms strongly driven by sustainability, but also to the proper balance between basic research and applied prospects.

**Conclusion**

Although built on strong industrial connection, the programme of the PC group is well balanced, leading to a very good output in basic and applied science. The viability of the group, which is active on a broad research front, might be guaranteed in the future by the coherent integration of two groups with relevant expertise, which was announced to the Committee during the on-site visit.

**Functional Polymer Colloids and Radical Polymerization**

| | | |
|---|---|---|
| Programme code: | TUE 7 | |
| Programme director: | Prof. dr. A.M. van Herk | |
| Research staff 2007: | 4,34 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 5 |
| | Relevance: | 4 |
| | Viability: | 4 |

*Short description*
The research programme is centred on the design and preparation of functional polymer (nano)particles, primarily using the free-radical technique of emulsion polymerization. The synthetic work is combined with detailed physical chemical studies on structure-property relationships and (controlled) radical mechanisms in homogeneous and heterogeneous systems. The ultimate goal of the programme is to develop increasingly complex materials for advanced applications while actively pursuing sustainable technologies.

*Quality*
After the retirement of Prof. German, the former leader of the Polymer Chemistry group, in 2000, Prof. Van Herk maintained the expertise of this group by focusing on (controlled) radical polymerisation in emulsion from the mechanistic point of view and as a tool to prepare functional polymer colloids.

The small size of the group that he headed during the evaluation period (2001-2007) can be accounted for by the dual role played by Prof. Van Herk as programme leader and Director of Education (60% of the time) in the department. His expertise in emulsion polymerisation is well established as assessed by an active role in the Dutch Foundation Emulsion Polymerization consortium and by invited and keynote lectures in international conferences.

*Productivity*
The scientific productivity is excellent considering the size of the group, with a large number of PhD theses and the best bibliometric data in the Polymers and Composites departmental sub-discipline.

*Relevance*
The research programme is not only scientifically relevant, but it also delivers sound technological information to the industry, which is a partner of the group (55% funding via research contracts).

*Viability*
The vi ability of the group offers optimistic prospects for the future with the full availability of Prof. van Herk for research in 2009 and new lines of research by Dr. Heuts, who was appointed full-time professor in 2006. Moreover, this group is expected to participate actively in an enlarged Polymer and Technology group, together with the groups of Prof. Koning and Dr. H. Goossens, which would strengthen the desired long-term expertise on established polymerisation techniques and the large scope of related (nano/bio/hybrid) materials

**Conclusion**

As a whole, the research activity of this group merits the qualification of 'very good', a significant achievement  given a sub-critical size, and the sizeable time investment of its leader in the educational activity of the department., Prof. van Herk is now again fully available for research, and the integration of his group into an enlarged group devoted to Polymer Chemistry and Technology would make sense and would contribute effectively to the impact and viability of the departmental research activities in this broad field.

**Materials and Interface Chemistry**

| | | |
|---|---|---|
| Programme code: | TUE 8 | |
| Programme director: | Prof. dr. G. de With | |
| Research staff 2007: | 16,32 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 5 |
| | Relevance: | 4 |
| | Viability: | 4 |

*Short description*
The group aims to perform fundamental and applied research in the field of materials science and technology with a strong emphasis on interface related phenomena and problems. The research programme focuses on the chemical and structural understanding and control of structure-property relations for a broad range of multi-phase materials as relevant to widely varying applications.

*Quality*
The group has a solid, very good reputation in the area of mechanical testing of surfaces and of sophisticated microscopy techniques. The research on solar cells and biomimetic structured hybrid materials has been noticed and well received in the international community.

*Productivity*
The productivity of the group as measured by publications in refereed journals, by the (considerable) number of PhD theses defended during the assessment period and by the number of patents filed is excellent.

*Relevance*
The group develops expertise in important characterization techniques such as mechanical methods of studying of surfaces or sophisticated electron microscopy. This creates the possibility of interesting collaborations with teams in many areas of material science. The topic of solar cells is timely, but even more traditional work on coatings is of industrial relevance.

*Viability*
Some of the experimental tools mastered by the group are unique and there should be increased demand for collaboration. The younger members of the staff are very good scientists, interested in important and relevant topics. They proved that they can conduct a high quality research so that the perspective for growth and development are good, especially if appropriate advancement routes can be identified to keep them within the programme. To be less vulnerable and realize its development potential, the group should diversify its funding sources.

**Conclusion**
The group has an internationally acknowledged expertise in sophisticated characterization tools and produced several noticeable findings while sustaining a very consistent productivity.

**Chemical Reactor Engineering**

| | | |
|---|---|---|
| Programme code: | TUE 9 | |
| Programme director: | Prof. dr. ir. J.C. Schouten | |
| Research staff 2007: | 13,47 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 5 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The emphasis of the research of the group is on the design and operation of microstructured reactors and structured multiphase reactors for a wide range of applications and processes. The group's research focuses on understanding and controlling the interaction of physical transport and (catalytic) reaction processes. The aim is to develop and apply novel technologies for efficient, safe and robust (micro)structured multiphase reactors, which show the best productivity by a dedicated design. For the future the installation of a micro-fluidics laboratory for complex chemical synthesis in close cooperation with Macro-Organic Chemistry (TUE 1) is planned under the umbrella of the recently founded Institute for Complex Molecular Systems (ICMS).

*Quality*
The group belongs to the world-leading research groups in process intensification through microstructured reactors. This position has been underpinned by the appointment as part-time professor of V. Hessel, director of one of the leading developers and suppliers of micro-devices. The head of the group, presently chairman of the European Working Party on Chemical Reaction Engineering, has an excellent scientific reputation. This is reflected by an extraordinary amount of high level research funds, among them several grants of excellence like the Advanced Investigator Grant of the European Research Council, as well as top personal grants from Dutch funding agencies.

*Productivity*
The group has a good publication record in the leading journals of its field. The number of PhD students has been consistently high. The most obvious sign of its productivity is the high number of research funds attracted in recent years.

*Relevance*
Process intensification through microstructured devices is presently considered a most attractive research topic, both by industry and funding agencies. This is reflected in a very good funding situation. The group presently seems to be the biggest and the best equipped European university group in this area.

*Viability*
Process intensification by microtechnology is an attractive research area, although the presently favoured focus on highly sensitive reactions seems to have a limited range of applications. In order to sustain the attractiveness, it will be necessary to demonstrate the advantages of microtechnology in a broader application range. The intended cooperation with Macroorganic Chemistry (TUE1) in order to explore the use of microtechnology for a target-oriented synthesis of complex organic molecules could be such a promising new application area.

**Conclusion**

Within the broad field of Chemical Reaction Engineering the group has decided to focus on micro-process technology. Although many Dutch university groups intend to extend their work in this area, this group has the best standing at present, due to a dedicated long-term commitment, ample research grants and qualified staff. The intended extension of micro-technology into the synthesis of complex organic molecules seems an equally promising and original next step.

**Process Systems Engineering**

| | | |
|---|---|---|
| Programme code: | TUE 10 | |
| Programme director: | Prof. dr. ir. A.B. de Haan | |
| Research staff 2007: | 4,6 | |
| Assessments: | Quality: | 3 |
| | Productivity: | NA |
| | Relevance: | 3 |
| | Viability: | 3 |

*Short description*
The group performs research in the area of affinity separation process systems engineering. Emphasis is placed on research concerning affinity solvent separation systems, affinity solid separation systems, and system integration and equipment intensification. The research focuses on methodology development for the integrated design of affinity separation agents and affinity separation process systems from a wide range of application perspectives. The ultimate aim is to establish the intensified, sustainable processes required for value-generating products of the future, such as specialty chemicals, pharmaceuticals and functional food ingredients.

*Quality*:
The group started activities in September 2006, when Prof. De Haan came to Eindhoven from Twente University, where he had worked in the Department of Separation Technology. The focus of the work in Eindhoven is on:

- the development of new separation agents, based on the specific requirements of the products to be separated from reaction mixtures, with ligand affinity a major criterion.
- estimates of costs of newly developed separation agents and associated technologies, to enable the selection of best combinations of separation effectiveness and cost.

This approach could be a useful addition when done with the necessary depth and in consensus with other partners in Process Engineering.

*Productivity*:
Most of the publications of the group date from the Twente period. No PhD theses have been produced in Eindhoven. It is therefore too early to draw conclusions on the productivity of this group.

*Relevance*:
Effective chemical processes depend on well designed reaction systems, and on subsequent separation processes that have been optimized relative to the desired product and chemical process utilized. As a result, the activities of the Process Systems Engineering group could be relevant. Full relevance will depend on an appropriate choice of topics, depth of analysis and the constructive interaction between the Chemical Reaction and Process Systems Engineering groups.

*Viability*:
With the present approach, the potential of the contribution of Process Systems Engineering to the Chemical Reactor Engineering group has not led to results that would take away con-

cerns about the longer term viability of the PSE group. Rearrangement of the chosen topics and the development of the necessary interactions between these two groups will be needed to insure eventually viability of the Process Systems Engineering group.

**Conclusion**

Effective separation processes, as envisioned by this group, are potentially important in the development of optimized chemical reaction systems. In making the transition from the former Twente Separation Technology group to a new Eindhoven group, the group of Prof. De Haan has not convinced the Committee of the present approach. An in-depth discussion with other partners in the section of Process Engineering and eventual rearrangement and/or rethinking of this approach is strongly recommended.

**Separations and Transport Phenomena**

| | | |
|---|---|---|
| Programme code: | TUE 11 | |
| Programme director: | Prof. dr. ir. P.J.A.M. Kerkhof | |
| Research staff 2007: | 3,1 | |
| Assessments: | Quality: | 3 |
| | Productivity: | 2 |
| | Relevance: | 3 |
| | Viability: | NA |

*Short description*
The research is aimed at improved understanding of molecular transport phenomena, and the implementation of this knowledge in separation and reaction processes. The aim is to contribute to sustainable process technology in membrane and adsorptive separations via simulation of fundamentals of transport phenomena, such as refinement of multicomponent transport equations, and mesoscopic simulation.

*Quality*
The Committee feels that the moderately-sized research group of Prof. Kerkhof has authored a few scientific highlights that are very relevant for this field, viz. the novel theory for multicomponent fluid transport, the simulation of the dynamics of entangled polymers and the modelling of fluid dynamics at the mesoscopic level. The publications are in the better journals of the discipline. The bibliometric study shows a modest output, although the quality of the publications is of an average international level.. The average number of citations per paper is low, but not atypical for this discipline. The director is appreciated among his peers for the degree of theoretical innovation in his papers. When the group has been restructured, new expertise was brought in (Dr. Peters in 2004). The work on mesoscopic theory has developed into a successful scientific activity.

*Productivity*
The number of PhD theses defended in the evaluation period is limited. In addition to this, the number of scientific papers is not abundant, even when the very modest size of the group is taken into account.

*Relevance*
The scientific work of Prof. Kerkhof has not remained unnoticed by his peers. The recent success in solving long-standing open problems in multi-component transport is worth mentioning in this respect. The work of fluid dynamics at the mesoscopic level (expertise of Dr. Peters) is highly relevant and internationally visible.

*Viability*
The Committee recommends that the activities of the group as a separate entity be discontinued. In this respect, the Committee was pleased to see that the expertise of Dr. Peters is already accommodated into another (experimental) research group, where this promising approach could be support for the experimental work and room is available for further growth and development of the modelling part. The Committee considers the work on transport to be important enough to require validation in literature before the group director retires.

**Conclusion**

Though the quantitative output of the research of this group has been rather modest, the work is appreciated by the peers and relevant for the discipline. The Committee urges the authors to validate the research through publications, bearing the upcoming retirement of the programme director in mind. The Committee supports the effort of the department to retain the specific expertise in the area of mesoscopic modelling.

**Molecular Heterogeneous Catalysis**

| | | |
|---|---|---|
| Programme code: | TUE 12 | |
| Programme director: | Prof. dr. R.A. van Santen | |
| Research staff 2007: | 29,58 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 4 |

*Short description*
The research employs an integrated approach for the molecular description of catalytic processes. Computational and experimental studies are combined to study catalytic reaction mechanisms and catalyst synthesis. The mission aims at developing predictive methods and theories that relate catalyst performance to catalysis structure and composition, and to design new catalytic systems to resolve key technological problems.

*Quality*
The output of the programme is characterized by a specific and unique approach combining experimental with computational methodologies. A series of highly relevant and timely items appear on the list of topics studied, giving an excellent overview of the potential of today's molecular heterogeneous catalysis for sustainable chemistry. The best journals of the respective disciplines are used for publication, including top-journals with broad impact in the chemical community. The group has continued to achieve top-quality level, even during the period when the director took up other major responsibilities. Even during this period (covering a significant part of the review period) the international visibility of the director remained very high, though most of the more junior associates have acted as valid substitutes.

*Productivity*
The research output after normalisation is above the international average. Given the abundantly available research staff of the group, the number of high quality papers and of defended PhD theses, the Committee feels that the performance of the group as a whole merits the qualification 'very good'.

*Relevance*
The specific approach of the group allowed them to select the more timely topics in heterogeneous catalysis and formulate new conceptual basis for sustainable catalytic processes and procedures. Occasionally, developed knowledge has been patented and implemented via spin-out initiatives (cf. new silsesquioxane chemistry for catalysis).

*Viability*
The SWOT analysis shows that the group realizes that the coherence has decreased with extension of the group, while the independence of the individuals has increased. As the succession of Prof. van Santen has been settled, the Committee recommends that the successor pays attention to increase the coherence by sticking more tightly to the typical 'Van Santen approach' that today has far from lost its merits. This does not require redefinition of topics, because they, on the whole, reflect the questions of the day, but only refocusing on the connection between advanced experiment and theoretical validation / prediction.

**Conclusion**
The decreased daily attention of the director to the research of the group is not reflected in the quality of the output during the period of the evaluation nor in the relevance of the approach and the selected research topics. The productivity of the group, however, might have suffered to some extent. With the new director, the viability of the group remains very good, although the Committee would appreciate seeing efforts to enhance coherence among the senior researchers, which implies continued and intensified use of the 'Van Santen approach'.

**Homogeneous Catalysis & Coordination Chemistry**

| | | |
|---|---|---|
| Programme code: | TUE 13 | |
| Programme director: | Prof. dr. D. Vogt | |
| Research staff 2007: | 7,6 | |
| Assessments: | Quality: | 5 |
| | Productivity: | 4 |
| | Relevance: | 5 |
| | Viability: | 5 |

*Short description*
The group strives towards an integrated approach of efficient and sustainable catalytic conversions. New generic methods for catalyst immobilization and compartmentalization for catalyst recovery and cascade reactions are employed as is the utilization of renewable feedstocks. The group also uses a molecular approach towards chemo-, regio-, and enantioselective processes, including mechanistic studies and ligand design. The goal is to create new routes with improved sustainability for existing products based on alternative feedstocks and renewable resources, to improve the fundamental understanding of molecular control mechanisms and to develop applicable catalytic systems for the production of intermediates and building blocks for (nano)materials (hybrid inorganic/organic, polymers) and fine-chemicals (pharma, food & feed additives, flavours and fragrances).

*Quality*
The field normalised quality index for the output of the Homogeneous Catalysis and Coordination Chemistry Group is significantly above the international average. The publications are found in the top journals of many different fields of chemistry such as coordination chemistry, homogeneous catalysis, organometallic chemistry, and polymer chemistry. A significant fraction can also be found in the general chemistry journals. The Vogt group is internationally recognized for its work on design of homogeneous catalysts for C-C formation reactions via a combined effort involving ligand design, organometallic chemistry and advanced mechanistic work. The group is also one of the pioneers in the design of immobilized catalysts. The group is world leading in the area of POSS chemistry. Undeniably, the group belongs to the top in the area of directed catalyst design.

*Productivity*
The scientific productivity comprises, among other things, over 80 papers and ten PhD theses. Given the number of research staff involved, this is a very good score, although the Committee thinks that the 'excellence' status is in easy reach by applying an intensified search policy for excellent PhD students, who will be confronted with a stimulating and state-of-the-art scientific environment.

*Relevance*
In addition to the strictly scientific output, a significant number of patents has been assigned to the group, allowing valorisation via (successful) spin-out initiatives, e.g. via the DPI.

*Viability*
All senior staff members are recognized experts in their respective fields. The Committee is convinced that many opportunities will continue to be available to assure continuation of

scientific performance at this very high level. However, the group seems to feel a threat for the future rejuvenation of the topics, because of the absence of a funding scheme for small innovative projects.

**Conclusion**
The Committee has the impression that this group is operating close to its optimal efficiency, although some attention should be given to a further enhancement of the productivity. The topics are all highly relevant and only seem to require occasional actualisation. Attention to and confrontation with significant developments by others, will keep the group at the international forefront.

**Physical Chemistry of Surfaces**

| | | |
|---|---|---|
| Programme code: | TUE 14 | |
| Programme director: | Prof. dr. J.W. Niemantsverdriet, Prof. dr. B.E. Nieuwenhuys | |
| Research staff 2007: | 7,2 | |
| Assessments: | Quality: | 4 |
| | Productivity: | 4 |
| | Relevance: | 4 |
| | Viability: | 4 |

*Short description*
The mission of the group is to link the structure and composition of surfaces in atomic detail to their reactivity, by exploiting a range of advanced surface sensitive tools, kinetic analysis and computational methods. Applications include polymers, coatings, natural fibres and thin oxide films.

*Quality*
The Physical Chemistry of Surfaces Group is of a very good level, and the director and other senior researchers are prominently present on the international scene. The group, of limited size, is focussed on coherent topics that can be categorized as rather traditional for this field. The normalised quality index for the scientific output is average, and the average number of citations per publication can stand improvement. The Committee agrees that this may be related to the fact that activities of one of the directors are not directly related to top research.. The quality of the output could also be enhanced by careful targeting of the most appropriate journals. The Committee feels that with the impressive state-of-the-art equipment available, the group should try to make an effort to play in a creative way with the specificity of the research tools.

*Productivity*
Although the productivity in general deserves the qualification 'very good', the Committee feels that the balance between quantified research output and available research staff should be improved before reaching the qualification 'excellent' . It is also recommended that the group develops an intensified search policy attracting post-docs and PhD students and maintaining a good balance between research and servicing.

*Relevance*
A number of topics being of a rather traditional nature, the relevance of the approach / output will not suffer from directed attempts of occasional actualisation and revitalization. The balance between research and service with the state-of-the-art infrastructure should be assessed continuously in a very critical way. The combination of energy related catalysis with the surface characterisation of model catalysts is one of the topics that should be pursued, not only for the interest expressed by a particular private partner, but mainly to gain international exposure and visibility.

*Viability*
Given the available infrastructure, the directors should consider to undertake actions that result in a minor though significant growth of the number of active researchers / technical staff. A creative and concerted application of the surface characterisation and computational

methodologies on relevant catalytic reactions and solids, will provide a promising level of viability for the coming years.

**Conclusion**

The group in every aspect deserves the label 'very good'. The Committee recommends the group to actively try to attract promising young researchers, to continuously keep the balance between research and service in mind, and to use the specific approach in a creative way in order to solve upcoming generic problems in modern catalytic science.

# APPENDICES

# Appendix A: Curricula vitae of the Committee members

**Prof. Frans De Schryver,** chairman of the Committee, is endowed visiting professor at the Catholic University of Leuven. For many years he has been involved in the area of photochemistry and photophysics. His research has focused on the fundamental aspects of photochemistry and photophysics and their use in the study of the physicochemical properties of complex systems. During the last 10 years he contributed primarily to the emerging field of time- and space-resolved (photo)chemistry, scanning probe microscopy, optical microscopy, single-molecule spectroscopy and nanoscience. He is a member of the Royal Academy and Editor in Chief of Photochemical & Photobiological Sciences, Associate Editor of ChemPhysChem and a member of the Editorial Board of Angewandte Chemie and Chemical Physics Letters. He has received a Senior Humboldt and a Max Planck Research Award and has served as an evaluator of the Dutch chemistry Departments, ICES/KIS 3 and numerous international nanoscience programmes.

**Prof. Dr. Ir. Gerhart Eigenberger** was director and chairholder of the Institut für Chemische Verfahrenstechnik of Stuttgart University from 1986 to 2004. His research interests are in Chemical Process Engineering with a focus on Chemical Reaction Engineering, electro-membrane processes, including membrane fuel cell systems and adsorption processes. He is a member of the Heidelberg Academy of Sciences and of Acatech, the German Academy of Science and Engineering

**Prof. Dr. Pierre Jacobs** is special visiting professor at the Department of Microbial and Molecular Systems of the Catholic University of Leuven. His research interests include heterogeneous catalysis, oxidation and enantioselective catalysis, supramolecular catalysis, high throughput catalysis, catalysis related to fuel and biofuel production, organic analysis with chromatographic techniques, fat chemistry and technology.

**Prof. Dr. Robert Jérôme** was director Center for Education and Research on Macromolecules (CERM) at the University of Liege till 2007. His search interests include Controlled Polymerization and Macromolecular Engineering (Design of macromolecular structures and architectures using new methods for achieving living and controlled polymerization, in the field of anionic polymerization, ring opening polymerization and radical polymerization), Conducting polymers (synthesis of conducting nanowires by electrochemical polymerization, preparation of ion-exchange materials based on conducting polymers, conductive organic coatings well-adhering to metal and carbon substrates of various shapes), Supramolecular Chemistry (ionomers and related materials, liquid crystal copolymers, amphiphilic copolymers, interactions between polymers and surfactants in solution or at solid/liquid interfaces), Biomaterials and Environment-Friendly Materials (bioresorbable macroporous supports prepared by polymer/solvent phase separation and by supercritical CO2 expansion, nervous regeneration and tissue engineering, development of new (bio)degradable materials by environment-friendly methods), Blends and composites.

**Dr. Ludwik Leibler** is a researcher in Centre National de Recherche Scientifique (CNRS) which he joined first in Strasbourg then in Paris where he worked on theoretical and experimental aspects of polymer self-assembly and dynamics, interfaces, gels and charged polymers. From 1996 to 2003 he was the founding director of a joint laboratory between CNRS and chemical company Elf Atochem (later AROFINA) which regrouped researchers from academia and industry. In 2001 he became an Adjunct Professor of Soft Matter and Chemistry at École

Superieure de Physique et Chimie Industrielles in Paris where his research interests include influence of molecular disorder on mesoscopic structure and properties of polymer materials, impact resistance, fracture and adhesion, design of stimuli responsive materials and supramolecular chemistry. Dr. Leibler is a Foreign Associate of the National Academy of Engineering. Other distinctions include CNRS Silver Medal, French Polymer Society Prize, and France IBM Prize in Material Science. He is an associate editor of Macromolecules.

**Prof. Dr. Nava Setter** is director of the Ceramics Laboratory of the École Polytechnique Fédérale de Lausanne (EPFL) since 1989. The Ceramics Laboratory is a large laboratory in the area of piezoelectric and ferroelectric materials, collaborating with numerous industries and academic laboratories in Europe and elsewhere. She worked in the area of electronic materials at the Pennsylvania State University, USA, at the Physics Department in University of Oxford, at the Chemistry Department of the University of Geneva, Switzerland, and in Haifa, Israel. Her current scientific research interests include non linear dielectrics for high frequencies, relaxor ferroelectrics, piezoelectric/ferroelectric thin films and their interface with other materials, and small structures for sensors and actuators and for applications in electronics. She has been member of the Swiss Academy of Technical Sciences since 1995, was a Meirhof invited professor in the Weizmann Institute of Science during Winter 1999 and invited professor in the Tokyo Institute of Technology during Spring 2007. She received the SKORE-A award, the ISIF outstanding achievement award and the Ferroelectrics-IEEE recognition award. She served as the distinguished lecturer of the UFFC-IEEE during 2005. She is Fellow of the IEEE, a Fellow of the World Academy of Ceramics and Honorary Professor of the Xi'an Jiaotong University.

**Prof. Dr. Bernard Witholt** was Professor and Chairman of the Institute of Biotechnology ETH-Hoenggerberg HPT (1992-2006). From 1972 to 1992 he was a member of the Biochemistry Laboratory of the University of Groningen, where he co-founded the Groningen Biotechnology Centre (1980), the Zernike Science Park (1983), the BIOSON Institute (1987), and the Groningen Biosciences and Biotechnology Institute (1992).

# Appendix B: Explanation of the SEP scores

| | |
|---|---|
| **Excellent (5)** | Research is world leading.<br>Researchers are working at the forefront of their field internationally and their research has an important and substantial impact in the field. |
| **Very Good (4)** | Research is nationally leading.<br>Research is internationally competitive and makes a significant contribution to the field. |
| **Good (3)** | Research is internationally visible.<br>Work is competitive at the national level and makes a valuable contribution in the international field. |
| **Satisfactory (2)** | Research is nationally visible.<br>Work adds to our understanding and is solid, but not exciting. |
| **Unsatisfactory (1)** | Work is neither solid nor exciting, flawed in the scientific and/or technical approach, repetitions of other work, etc. |

*Quality*: This is to be seen as a measure of excellence and excitement. It refers to the eminence of a group's research activities, its abilities to perform at the highest level and its achievements in the international scientific community. It rests on the proficiency and rigour of research concepts and conduct; it shows in the success of the group at the forefront of scientific development.

*Productivity* refers to the total output of the group; that is, the variegated ways in which results of research and knowledge development are publicised. The output needs to be reviewed in relation to the input in terms of human resources.

*Societal relevance* covers the social, economic and cultural relevance of the research. Aspects are:

- societal quality of the work. Efforts to interact in a productive way with stakeholders in society who are interested in input from scientific research, and contributions to important issues and debates in society.
- societal impact of the work. Research affects specific stakeholders or procedures in society.
- valorisation of the work. Activities aimed at making research results available and suitable for application in products, processes and services. This includes interaction with public and private organisations, as well as commercial or non-profit use of research results and expertise.

*Vitality and feasibility*. This dual criterion regards the institute's ability to react adequately to important changes in the environment. It refers to both internal (personnel, research themes) and external (developments in the field, in society) dynamics of the group. On the one hand, this criterion measures the flexibility of a group, which appears in its ability to close research lines that have no future and to initiate new venture projects. On the other hand, it measures the capacity of the management to run projects in a professional way. Policy decisions and project management are assessed, including cost-benefit analysis.

# Appendix C: Programme of the site visits

| | |
|---|---|
| **Sunday, April 19, 2009: Arrival in Delft** | |
| 15:00 | Committee meeting: introduction to SEP; preliminary assessments, questions |
| **Monday, April 20, 2009: Delft University of Technology (TUD)** | |
| 9:00 | Faculty and Institutes (Biotechnology, Chemical Engineering, Multiscale Physics) |
| 10:30 | TUD 13: Multi-Scale Physics *(MSP)* |
| 12:45 | TUD 8: Nano-Organic Chemistry (NOC) |
| 13:30 | TUD 10: Opto-electronic Materials (OM) |
| 14:15 | TUD 9: Nanostructured Materials (NSM) |
| 15:00 | TUD 11: Product & Process Engineering (PPE) |
| 15:45 | TUD 12: Self-Assembling Systems (SAS) |
| 16:30 | TUD 7: Catalysis Engineering (CE) |
| 17:15 | Committee meeting (Faculty room) |
| **Tuesday, April 21, 2009: Delft University of Technology (TUD)** | |
| 9:00 | TUD 3: Bioprocess Engineering (BPE) |
| 9:45 | TUD 4: Environmental Biotechnology (EBT) |
| 10:30 | TUD 5: Enzymology (ENZ) |
| 11:15 | TUD 2: Biocatalysis and Organic Chemistry (BOC) |
| 12:45 | TUD 1: Analytical Biotechnology (ABT) |
| 13:30 | TUD 6: Industrial Microbiology (IMB) |
| 14:15 | Research and Education |
| 15:00 | PhD-interviews |
| 15:45 | Second interview Faculty and Institutes |
| 16:30 | Committee meeting |
| **Wednesday, April 22, 2009: University of Twente (UT), Enschede** | |
| 9.00 | First interview Discipline management ChE: faculty dean, chairman of the Discipline, 3 scientific directors, chairman of the Discipline |
| 10.00 | UT 7: Supramolecular Engineering |
| 10.45 | UT 1: Biomaterials & Tissue Engineering |
| 11.30 | UT 2: Catalytic Systems & Microdevices |
| 13.00 | UT 3: Chemical Reaction Engineering |
| 13.45 | UT 4: Inorganic Materials Science |
| 14.30 | UT 5: Organic Materials Science |
| 15.15 | UT 6: Separation Technology |
| 16.00 | Committee meeting |
| 17.00 | Research and Education |
| 17.30 | PhD-students |

| **Thursday, April 23, 2009: Eindhoven University of Technology (TU/e)** | |
|---|---|
| 9:00 | Institute: Department of Chemical Engineering and Chemistry |
| 9:45 | Research and Education |
| 10:15 | Introduction to the cluster Process Engineering |
| 10:30 | TUE 9: Chemical Reactor Engineering |
| 11:00 | TUE 10: Process Systems Engineering |
| 11:30 | TUE 11: Separations and Transport Phenomena |
| 13:45 | Introduction to the cluster Catalysis |
| 14:00 | TUE 12: Molecular Heterogeneous Catalysis |
| 14:30 | TUE 13: Homogeneous Catalysis & Coordination Chemistry |
| 15:00 | TUE 14: Physical Chemistry of Surfaces |
| 15:45 | Introduction to the cluster Polymers & Composites |
| 16:00 | TUE 8: Materials and Interface Chemistry |
| 16:30 | TUE 6: Polymer Chemistry |
| 17:00 | TUE 7: Functional Polymer Colloids via Radical Polymerization |
| 17.30 | TUE 5: Polymer Technology |
| 18:00 | Committee meeting |
| **Friday, April 24, 2009: Eindhoven University of Technology (TU/e)** | |
| 9:00 | Introduction to the cluster Macromolecular Chemistry and Molecular Materials |
| 9:15 | TUE 1: Macro-organic Chemistry |
| 9:45 | TUE 3: Supramolecular Polymer Chemistry |
| 10:15 | TUE 2: Molecular Materials and Nanosystems |
| 11:00 | PhD students |
| 12:00 | Committee meeting |

# Appendix D: Reaction MSP-TUD

**Reaction on the review of the Multi-Scale Physics (MSP) Programme at TU Delft**

First of all we thank the evaluation committee for the work they have done. We understand how difficult such an evaluation task is. Our MSP programme combines both physics and chemistry. The multidisciplinary approach is required as we do research and education in a competitive field in which all disciplines need to be combined. But this approach makes it extremely difficult to evaluate the results on a particular field of expertise. We feel that the scores for the programme Multi-Scale Physics (MSP) received in the 3TU Research Assessment 2003-2007 (*viz.* Quality: 3 - Productivity: 4 – Relevance: 3 – Viability: 3) do not justify and do not reflect the high quality of our work. In the table below we have put together the latest citation analyses of our group:

| | *CPP/JCSm 1991-2000* | *CPP/FCSm 1991-2000* | *CPP/JCSm 1997-2006* | *CPP/FCSm 1997-2006* | *Rating 2002* | *Rating 2009* | *#P (ISI) 2010* | *CPP (ISI) 2010* | *h-index 2010* |
|---|---|---|---|---|---|---|---|---|---|
| *vdAkker + Mudde + Kleijn + Roekaerts* | | | 1.31+ | 1.56+ | | 3-4-3-3 | 224 | 10.7 | 26 |
| *vdAkker + Mudde + Kleijn* | 1.35 | 1.51 | | | 5-3-5-5 | | 189 | 12.1 | 26 |
| | CPP/JCSm 1994-2003 | CPP/FCSm 1994-2003 | | | | | | | |
| *vdAkker* | 1.59 | 1.64 | 1.66+ | 1.98+ | | | 106 | 13.7 | 21 |
| *Mudde* | 2.06 | 2.17 | 2.02 | 2.70+ | | | 61 | 11.2 | 15 |
| *Roekaerts* | 1.75 | 2.98 | 1.05 | 1.52 | | | 78 | 8.7 | 15 |

MSP's current CPP/FCSm number, *viz.* 1.56+, is comparable with those of several similar programmes in Delft, Twente and Eindhoven. These groups were scored 4-4-5-5, 5-4-5-4 or even 5-5-5-4.

We think that the Evaluation Committee has focused the evaluation of the MSP programme strongly on the chemistry part of our work. While MSP's core expertise is much more on computational and experimental physics (fluid mechanics, turbulence, transport phenomena). The research of MSP can be best described as an independent self-sustaining branch of strongly computational science aimed at significantly reducing empiricism in describing fluid flow and transport processes. The applications of MSP's expertise are not restricted to Chemical Engineering, but are also relevant to such divergent fields as Environmental Engineering (atmospheric dispersion, clouds formation, earth magnetic field), Health (blood flow, magnetic drug targeting), Civil Engineering (sediment transport, dredging) and Nuclear Engineering (two-phase coolant systems). Nevertheless, the field of chemical engineering and the chemical process industries are the first to benefit from MSP's expertise (as an illustration: the

Derksen & Van den Akker 1999 paper is the 6th most cited of all 3,430 papers published during the last decade in AIChE J), most of the papers so far having been published in top journals such as AIChE J, Chem.Eng.Sci. and Int. J. Multi-Phase Flow – this being the reason for participating in this Assessment.

We will read the criticism of the evaluation committee and we will take advantage of the suggestions made. But we also feel confident with our research direction and we will keep developing the computational multi-scale approach of flow and transport phenomena with applications in the various engineering fields. MSP will further work to develop its own scientific portfolio and intellectual position. We will work in an integrated group of 4 independent full professors plus 2 part-time professor positions and our programme comprises 4 complementary themes each headed by one of the 4 full professors. With much confidence we look forward to the next evaluation of our group by the Physics committee in this year.