KTH International RAE 2008

REPORT PANEL 9: CHEMISTRY

GENERAL ASSESSMENT OF THE RESEARCH FIELD

The research in the four Units of Assessment (UoAs) within Chemistry is strong on an international scale. The research groups in some sub-fields are among the world leaders. Their strengths include both basic and applied research and research training of high quality and significant size. The UoAs interact in many ways with the outside world, for example through successful applied research in cooperation with Swedish industry. The researchers are not only key figures in international research cooperation, but also in the editorial work they undertake and as hosts for meetings in all areas of chemistry. They help promote interest in science and technology in the next generation of Swedish students, and also take part in the domestic debate on environmental and other issues.

Important strategic changes have taken place in the UoAs in recent years, particularly the merger of small groups into bigger units, facilitating interdisciplinary work. An example is the creation of the UoA for *Fiber and Polymer Technology* that took place about six years ago. It is now obvious that the benefits of this merger are substantial, although this only became clear after several years. The Unit today is very strong in many respects and some of the researchers are world leaders in their field. This is not only apparent through extensive publication, high citation counts, and patents, but also in the role played by the Unit with respect to international publishing, conferences, etc. The vitality of the group is outstanding, with a good age-profile and gender balance, and the main strategies that so far have been applied seem to work very well.

The basic research in the *Theoretical Chemistry* UoA is at the forefront of international theoretical and computational research. The productivity in terms of published papers, graduated PhDs, and computer software developed for quantum chemical calculations is outstanding. There is a positive attitude towards work on real life applications, for example in molecular electronics and photonics, and the Unit is involved in many cooperative projects. Nevertheless, at KTH alone there seems to be several additional opportunities for cooperation. The Unit has numerous young and brilliant foreign students, half of them from China, and has the prospect of continued growth and renewal.

The *Chemistry* UoA is strong in several respects, with high publication and citation rates, patents, and many excellent cooperative projects with industry. The solar cell group is among the world leaders, and the industrial NMR centre is an outstanding centre for interdisciplinary research and application. The surface and corrosion research group is about to establish an external partnership on campus that will create a world leading centre in corrosion research, and the large organic chemistry group is involved in innovative synthetic work. The Unit produces a large number of excellent PhDs.

The *Chemical Engineering* UoA is particularly strong within applied research, and has had long-term, productive cooperative arrangements with many leading industries, for example in energy systems. However, the age-profile in the Unit is very poor, many highly qualified

researchers are about to retire, and the gender balance is bad. In the next few years a clear strategy will be needed to redress these issues for the UoA to grow in strength and numbers.

UoA: Fiber and Polymer Technology

Performance Against Evaluation Criteria

Scientific Quality (basic research)

In 2002, the Departments of Pulp and Paper Chemistry and Polymer Technology were merged into the present unit for Fiber and Polymer Technology. The considerable benefits of this merger are now becoming increasingly clear as part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard.

The research in the UoA is concentrated in selected areas that are interrelated in a way that enables close collaboration between divisions. Basic research is carried out at a world leading level. Some research groups in this UoA are considered world leaders. The majority of papers have been published in the best journals in the field. The high number of citations indicates the influence their work has had in the international arena. Numerous scientists from the Fiber and Polymer Technology UoA have in recent years been invited as plenary, section and keynote speakers at international conferences. The UoA has also produced many exceptional PhDs.

The research in Fiber and Polymer Technology deals with following areas: wood chemistry and pulp technology, fiber technology, polymer technology, polymeric materials, coating technology, and biocomposites. Although the diversity of the research may be considered very large, a closer analysis shows that overlaps are considerable and important. For example, research in the areas of fiber and pulp technology, having wood as common source material, and developing understanding of processes specific for these areas, is beneficial for both fields. Similarly, some of the studies carried out within Coating Technology are supported by knowledge generated in Polymer Technology (e.g. grafting of aliphatic polyesters on cellulose fibers). Collaborative studies are also evident in the divisions of Biocomposites and Wood and Pulp Technology. Obviously, each division has its own main area of expertise, such as synthesis and characterization of dendrimers or fundamental studies of ring-opening polymerization, but clearly visible interrelations provide beneficial synergy.

Applied Research Quality

The majority of this UoA currently performs at a world-leading standard. Research topics are closely related to the needs of industry and constitute a sound basis for the development of methods suitable for production of macromolecular materials from renewable resources, such as synthesis of aliphatic polyesters by ring opening polymerization of monomers of natural origin, formation and modification of cellulose fibers. There is a strong awareness among the researchers in the UoA of the current need to change from standard polymer bulk products (of both synthetic and natural origin) to much more sophisticated and specialized nano-structured materials with properties tailored to highly demanding high-tech applications (e.g. for medical purposes).

More than 30 patents were granted to researchers of FPT during the period 2003-2007. A single researcher is the owner of 14 patents (nine granted and five pending) and the founder of five start-up companies.

The Fiber and Polymer Technology unit interacts via various networks with more than 250 companies. This, as well as the very significant amount of industrial support of the research carried on in the UoA can be considered evidence of the high quality of the applied research. During the period 2003-2007 external funding increased from about SEK 32 M (52% of the total funding in 2003) to about SEK 47 M (64% of the total in 2007). The external support came, in particular, from agencies promoting applied research as well as directly from industry. The latter increased from SEK 4 M (6.6 % of the total) to more than SEK 6 M (8.5 %).

The Fiber and Polymer Technology researchers have developed a number of materials with very special properties. These include, among other, biodegradable materials for tissue engineering, polymeric materials from renewable resources (not only cellulose and hemicelluloses but also starch, gluten chitosan and fatty acids), nanoporous cellulose and cellulose related nanocomposites as well as dendrimers. Particularly important is the development of a variety of methods for surface modification by adsorption or covalent immobilization of surface-active molecules or molecules with special functional groups. It is worth mentioning that studies on flame retardant composites are strongly supported by industry.

In spite of all these significant achievements related to applied research, it seems clear that the opportunities for even more industrial cooperation in the future are excellent.

Scholarship

Both senior professors and younger staff members of the UoA have an enthusiastic attitude towards education. The annual number of PhDs who graduated during the period 2003-2007 was high and fairly constant (12 ± 2 per year). About 90 % of PhD students who received degrees from the UoA during this period are currently involved in research and 64 % are working in industry. Several of the senior researchers in the Unit are members of international editorial boards of 30 scientific journals. Even more significant is the fact that the editorial offices of two important international polymer journals: both Biomacromolecules (published by the American Chemical Society, ACS) and the European Polymer Journal (Elsevier) are hosted by this UoA. Biomacromolecules is the only of the many leading ACS journals to have its editorial office located outside of the USA. Thus, some parts/individuals of this Unit were considered excellent.

The Unit is known for the organization of many important national and international seminars, workshops, conferences, and congresses (e.g. the large European Polymer Congress in 2003). In 2008 alone four workshops and conferences were organized.

The unit is also involved in a number of activities related to the wider scientific community, especially related to the very important recruitment of new talent to careers in Chemistry. The activities include summer research schools for high school students, programmes for visiting high schools, popular lectures in chemistry for high school students and teachers, performances at The Nobel Museum. Finally, the faculty members of the UoA have authored or co-authored seven textbooks.

Vitality and Potential

The high degree of vitality and potential of Fiber and Polymer Technology is related to the excellent gender and age balance. For example, among 20 professors, eight are women and 50 % of the PhD students are women; similarly, no less than six professors are below 40 in age. This is an indication of how vitality and potential is excellent across the majority of this UoA.

There is a remarkably high motivation among the researchers at all career levels. There are also several young researchers with an obvious potential to become future leaders; thus the coming retirements among the senior staff members are unlikely to cause serious problems. The relatively large number of young researchers with industrial and international post-doctoral experience further increases the potential of the division.

The large amount of funds received in grants, as well as the variety of these grants, creates a solid basis for the future educational and scientific activity of the division.

Strategy

The strategy of the UoA was outstanding with real potential to achieve. It aims at increasing collaboration within the Unit and enhancing the presently very visible synergistic effects of the merger between the departments of Pulp and Paper Chemistry and Technology and Polymer Technology that took place in 2002. It has been decided to focus the research activities (both through in-house and external collaboration) on products according to the following sequence of steps: synthesis → macromolecular design → modification → characterization → materials → devices. The successes of this strategy have, among other, made it possible to attract high quality students.

The quality and relevance of the graduate education in Fiber and Polymer Technology are likely to further improve with the introduction of entrepreneurship as a new subject. This is likely to make the competitiveness in the job market of graduates from the UoA even better through a broader understanding of market opportunities.

In spite of the many successes of the Fiber and Polymer Technology Unit, the insufficient core funding remains a problem. The lack of appropriate start-up funds is also problematical making it difficult to recruit new outstanding researchers from outside KTH; KTH needs to remain competitive in the academic community.

Even with the many excellent cooperative partners, the Fiber and Polymer Technology UoA might benefit from further increased collaboration, not only with industry, but also within KTH. In particular, stronger interactions with Theoretical Chemistry (modelling) and Chemistry (the NMR Centre) could be very beneficial.

UoA: Theoretical Chemistry

Performance Against Evaluation Criteria

Scientific Quality (basic research)

The basic research performed by this UoA is at a world leading standard and has a high international visibility. The productivity in terms of published research, graduated PhDs, and the computer software developed for quantum chemical calculations is outstanding and at the forefront of international theoretical and computational research.

The research activity of this UoA deals with simulation and modelling of chemical systems and processes. Such research can be carried out at various levels of detail and sophistication. At the simplest end one may seek a descriptive treatment using some canned software, while at the most ambitious end one seeks a full microscopic predictive treatment with special software. The impressive aspects of the research activity in Theoretical Chemistry are that the

activity covers the full gamut from one end to the other. Furthermore, the theory development and the associated computer code development has made possible detailed predictive treatment of complex systems and processes way beyond what is commonly done in theoretical chemistry elsewhere. The productivity is high in terms of publications in leading journals. Grant and contract funding is exceptionally high in comparison with theoretical and computational activity internationally.

The senior researchers in this UoA are invited plenary speakers at many of the major international conferences. Furthermore, the staff of the Unit has organized or co-organized in excess of twenty scientific conferences in the area of theoretical chemistry during the assessment period.

Applied Research Quality

The Unit has developed an applied research strategy that is more ambitious than what is common for theoretical chemistry, thus the Panel felt that part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. Impressive results of world leading quality have been reached in the areas of photonics and non-linear optics, modelling of enzymatic reactions, and molecular electronics. The applied research on protein dynamics and molecular magnetism although less developed, already shows great promise. Financial support is more than satisfactory in terms of external, including foreign, grants and contracts. The computer software suite of programs called DALTON is largely developed in-house and has seen wide international distribution (2000 user licenses in 35 countries). There has been considerable software development (CASCADE and DALTON) for applied research in physics, chemistry, biotechnology, and nanoparticle technology.

The overall activity in the area of molecular electronics applies to both basic and applied research and is of the highest international standard. It is here notable how the metal containing chain molecule synthesized at KTH in the Fiber and Polymer unit was studied both experimentally and computationally yielding very promising results for further development.

In spite of this high activity in applied research, the Unit could do more with joint projects both internally to KTH and externally. In particular, the Fiber and Polymer unit could participate even more than is currently evident in current projects and would give exceptional potential for external funding. Similarly the Chemistry and Chemical Engineering units have activities that could be significantly strengthened significantly by collaboration with Theoretical Chemistry. However, the initialization of such collaboration is of course only possible if the commitment comes from both sides.

Scholarship

Scholarship was considered to be excellent in some parts/individuals of the UoA. The professors of the UoA are internationally recognized and serve as evaluators of research proposals to EU programmes and for research councils in all Nordic countries. The senior professor serves on several international editorial boards. He also serves as director of two centres of excellence and the Unit is a member of a total of five centres of excellence. The Theoretical Chemistry Unit has hosted eight visiting scholars as guest professors during the assessment period. The senior researchers have participated in radio broadcasts on the role of science in society.

The academic staff of Theoretical Chemistry at KTH initiated and lectured at several international summer and winter schools on theory and computations, where they could share their expertise with scientists from around the world.

Vitality and Potential

Vitality and potential was excellent across the majority of the UoA. The overall activity is high and is internationally connected with numerous institutions abroad that send students and faculty to KTH to learn. The research activity has undergone an impressive growth during the period of assessment; adding new personnel and new research areas, such as (i) modelling of enzymatic reactions, (ii) protein dynamics, (iii) molecular electronics, and (iv) molecular magnetism and imaging using the properties of nanoparticles. There has also been an increasing collaboration with experimental sciences, both at KTH and elsewhere.

Theoretical Chemistry at KTH was also instrumental in the application, purchase, and installation in 2004 of the most powerful computer cluster in Sweden. Furthermore, this unit received twelve Research Council grants as well as five major grants to assistant professors during the period of assessment. This UoA also maintains an impressive multicultural research environment with twenty countries represented in the laboratory, with a very large presence from China.

A comparatively small group of senior academic staff, with good age distribution, provides training and education for a large number of students and postdoctoral research associates. More than forty research students were enrolled in 2007. However, the gender distribution of the academic staff needs some attention.

Strategy

The strategy presented was outstanding with real potential to achieve. Theoretical chemistry is presently taking steps to establish a Swedish meta-materials initiative. Furthermore, on the applied research side, there are plans to establish a company with hospital connections for imaging in medical diagnosis using properties of nanoparticles characterized with theoretical and novel computational tools. The Unit is also positioning itself to become a leader in the new facility MAX-IV (free electron laser), which is being planned and is one of the largest investments in Swedish research facilities.

Theoretical Chemistry at KTH is also involved in the planning of strategies for the development of theory and computations within modelling of chemical systems and processes. This project involves seven Nordic universities and is called the NORDFORSK-DALTON project.

The involvement in a large number (more than fifty) of diverse projects provides a degree of stability not provided by the extremely small core funding typical of the KTH environment. There is a demonstrated willingness to engage in more collaborative projects within KTH, but mechanisms and seed funding for such collaboration seemed somewhat lacking.

Theoretical Chemistry plans to seek a greater role in the undergraduate curriculum. The modern trend of increasing importance of modelling and simulation in all engineering sciences should make it imperative that such development takes place.

UoA: Chemistry

Performance Against Evaluation Criteria

Scientific Quality (basic research)

The Chemistry Department is divided into seven traditional groups, Analytical, Corrosion, Inorganic, Nuclear, Organic, Physical and Surface Chemistry of which the organic group is the largest. Each of these groups is highly acclaimed internationally. Three focus areas have been identified: Bioactive Molecules, Energy and the Environment, and Functional Materials and Surfaces.

Two new specialist centres in Industrial NMR and Molecular Devices, together with innovative method and technique development have been implemented that cross-divisional boundaries. These encompass organic synthesis, device manufacture and exploitation, and are recognized as leading in the international arena. The centres have extensive collaboration with leading groups, e.g. in New Zealand and Switzerland, A further rationale has been the combination of Corrosion Science, Surface Chemistry and Physical Chemistry into one grouping where synergism is likely to lead to new insights and developments. These include the application of surface chemistry techniques, such as AFM to study corrosion events and NMR methods to investigate the surface chemistry of nanoparticle systems.

The new corrosion/Physical/Surface group is the largest and one of the most experienced in Sweden. Another advantage of the regrouping is the increased potential for obtaining new EU and other international grants. The new building, which will house the combined group, is strategically placed next to relevant institutes including YKI and KIMAB. This will create one of the world's largest environments within corrosion research, although it will take some time to reach its full potential.

The professors and senior staff in Chemistry have been invited plenary/keynote lecturers at an impressive number of pure and applied international conferences. They have published extensively in key journals and have high citation counts. The Panel considered that part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard.

Applied Research Quality

The Panel judged that applied research also was mainly performed at an internationally high standard currently, with some areas performing at a world-leading standard. The Chemistry Unit is strongly focused on applied research as well, with over 40 companies donating over 500 KSEK each during the assessment period. Some of this collaboration takes place through local institutes (YKI, KIMAB and SP-Tratek) and government funded bodies (SKI, SSI and STEM). The burgeoning relationship between Corrosion Science, Surface Chemistry and Physical Chemistry will lead to new contracts and opportunities in the global industrial sector.

The two new centres are very promising. In terms of equipment, the centre for Industrial NMR has been highly successful in obtaining funds of 12M SEK for new and upgraded spectrometers from the Wallenberg Foundation and other sources. In methodology, the establishment of diffusion and charge sensitive NMR spectroscopy in multi-phase and multi-component systems as a tool for understanding the dynamics in complex formulation systems has led to a large number of potential collaborations with industry. The centre's work is an excellent example of how the development of highly innovative methodology can help solve industrial problems. One example is the use of 'in-situ' NMR to determine the liquid structure

of coatings in a paper coating machine; a prototype is currently being developed in the centre. Similarly, the centre for Molecular Devices draws on synthetic and electrochemical expertise in developing environmentally friendly materials for solar cells. They are also working in collaboration with other leading groups throughout the world.

The UoA is involved in a very large number of national networks and centres of excellence in areas which include drug delivery using bio-based materials, light harvesting molecules and materials with anisotropic conductivity.

Three spin-off companies have been formed and eight patents have been submitted during the review period. Clearly, there is a strong potential for even further exploitation of the fundamental and applied work that takes place in this UoA.

Scholarship

The Chemistry group comprises leading figures in Swedish science that have won many national and international awards for their work, and this was seen as an example of excellent scholarship in some parts/individuals of the UoA. Over the review period, Chemistry overall has employed 57 academic staff and over 900 papers have been published. Twenty PhDs have, on average, graduated each year; 90% are now working in research and development. There is also a healthy cohort of postdoctoral workers who make an important contribution to research and demonstrates the ability of the UoA to attract scientists from major universities from all over the world. This activity could easily be increased as these posts are fully funded and hence not encumbered by the researchers having to finance their own salaries.

During the review period, the leading staff members have made over 80 plenary/keynote lectures. As in all areas of science, publishing and refereeing publications is an essential task and staff members are involved in over twenty editorial boards.

Members of the UoA are actively involved in the six (hosted) centres of excellence and are regularly sought as members of international committees (e.g. COST). From a national perspective, the group supports the activities of the Swedish Chemical Society and contributes to the political debate on the funding of science. Outreach pursuits include contributions to television debates and making popular science presentations to children and young scientists.

Vitality and Potential

The UoA covers all areas of modern applied chemistry and vitality and potential is excellent in some parts of the UoA, good in the remainder. For instance, the Unit has been very successful in attracting high quality research students and highly motivated staff. Their graduates are eagerly sought after by industry. Substantial research funding has been attracted from outside sources; 60% of the total funding is external.

The UoA is actively involved in international large-scale facilities including neutron and synchrotron sources. The experience gained will be of direct benefit in taking full advantage of the synchrotron source being developed at the MAX-lab in Lund.

Several staff members have been able to make long term visits to other institutions and this has enormous benefit both in the dissemination of their own work and in exploring new research areas.

Strategy

Strategy was excellent but considered by the Panel to be challenging to achieve. One of the main strategies for the future is the re-organization of traditional research areas into new groupings that will open up new opportunities for research and funding. The new group within surface chemistry is a model that should be followed. The three new theme areas encompassing biology, energy, the environment and surfaces are highly appropriate and the challenge ahead is to make the UoA's contribution to these areas distinctive.

There are many projects in Chemistry that are paralleled by work in the Theoretical Chemistry unit and could easily benefit from collaboration with them. There seems to have been a sense of reluctance to do so in the past and this should be addressed in the coming years.

Recruiting and retaining younger staff is a priority, but also finding ways to make positions at KTH more internationally attractive (even attractive for researchers elsewhere in Sweden). There is a tendency for in-breeding of researchers, also seen in other UoAs in this Panel, a habit which should be limited. The appointment of young staff to four-year fixed term posts (which are fully funded) is good but more is needed as well as clear career paths.

The projects in nuclear waste disposal in Chemistry are timely and innovative but would benefit from the extensive environmental expertise in this field within Chemical Engineering (although the leading expert there is now retired).

The replacement of retiring staff must take place, bearing in mind the future direction of the UoA and in particular the new theme areas. The situation in Inorganic Chemistry after retirement of a senior researcher needs to be resolved. The age structure in Chemistry overall is reasonable but can be improved as can the gender balance which does not reflect the relative number of talented men and women at the postgraduate level. Sweden however, does provide excellent facilities for child care and generous parental leave and this has encouraged female staff to return to KTH from abroad.

In order to fertilize ideas across the section, a series of PhD surgeries has begun in the new corrosion/Physical/Surface group. The idea is that PhD students discuss their current research problems in order to find new inspiration, and this helps build new collaborations from the bottom up.

UoA: Chemical Engineering

Performance Against Evaluation Criteria

Scientific Quality (basic research)

The majority of the UoA currently performs at an internationally high standard. The research directions of Chemical Engineering are traditional and are defined in a close cooperation with key stakeholders, especially industry. This has also lead to a strong external funding for applied research projects by external stakeholders. The present funding situation in Sweden does not support "basic" chemical engineering research to any great extent, and thus the availability of "free" research money for more radical, new chemical engineering research has been limited. This has also strengthened the applied nature of research in this UoA. However, the generic chemical engineering tools; material and energy balances, transport processes, chemical engineering thermodynamics and kinetics, separation processes, chemical and

electrochemical reaction engineering and process chemistry are and have been very useful in a wide range of applications.

Chemical Engineering has approached a 'stage gate' with respect to its future directions; the age profile of the chemical engineering staff is unsatisfactory and strong measures to correct this situation must be taken. Corrective actions require stable long-term funding, which generate opportunities to direct future activities towards new strategic initiatives. The present situation offers an opportunity to vitalize chemical engineering research activities in new areas, and especially within the main focus areas of bio-energy and the environment. The importance of both these areas will continue to grow in the future.

Chemical Engineering has a long-lasting tradition in several research areas: bio-energy, including extended use of biomass and biomass gasification, electrochemistry, nuclear-waste storage, and fuel cells. The research in these areas is of a good international standard. Other important areas of research include catalytic combustion and catalytic reforming, crystallization, and energy systems in mobile applications (vehicles) which are of a high international standard and are highly relevant to the cooperating industries. Research results are usually published in well-recognized chemical engineering journals as well as in conference proceedings.

However, in order to enhance international networking, research cooperation, and to improve the international visibility Chemical Engineering might consider building smaller international competence centres consisting of around five research laboratories in its various research fields. The participating laboratories would focus on their own fields of expertise and through enhanced collaboration share their most unique and advanced research tools with each other.

Applied Research Quality

The majority of the UoA currently performs at a world-leading standard. The current research problems are derived from the close cooperation with industry, which provides very strong external funding. As indicated above, Chemical Engineering has identified major applications, including energy systems in vehicles, bio-energy, environmental technology, chemical production engineering and technology for developing countries.

The long lasting, strategic partnerships with many major leading industrial companies include AB Volvo, AstraZeneca and Akzo Nobel. The well-educated PhDs, graduated from Chemical Engineering, are highly appreciated by Swedish employers and are widely employed throughout the relevant industries. Chemical Engineering has also been involved in the establishment of new start-up companies such as Kemakta Konsult Ab, Cellkraft and myFC.

Scholarship

A long lasting collaboration has been initiated with developing countries through different technology projects. A good example is the research cooperation with the Technical University of Managua (UNI), Nicaragua, which started in 1986. The Faculty of Chemical Engineering of UNI is now taking steps towards establishing a sustainable research environment by starting a Master level program. The practical research cooperation involves, e.g., technology development for coffee drying, chitosane-based purification of water, and the development of new insecticides.

The Panel felt that part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. For example, the professors and staff

of Chemical Engineering are members of several scientific committees, advisory boards, and policy committees. Their work is characterized by a wide networking both internationally and nationally. However, the future development of Chemical Engineering requires a stronger visibility in selected strategic and fundamental research areas.

The UoA has actively participated in the debate on environmental and energy-related issues, through comments, presentations, and articles in different well-recognized channels, and through forums for sustainable development. One of the targets must be to influence and generate a more positive attitude towards chemistry and chemical engineering in the wider society.

Vitality and Potential

Vitality and potential was considered good in some parts of the UoA, but it needs to be improved in the remainder. For instance, the UoA is able to attract and recruit both undergraduate students and research students. However, Chemical Engineering is not able to convince a sufficient share of young researchers to continue their career within university research after graduation. The newly graduated PhDs are primarily looking for positions in industry.

A positive feature is the successful creation of several spin-off companies based on ideas developed in Chemical Engineering. Both new graduates and research staff members are involved in these. Among others, the participation in several EU-funded projects has paved the way for wide and extensive international cooperation.

The unsatisfactory "hourglass" shaped age structure of the chemical engineering staff is a serious problem and must be coped with before renewal and vitalization can be achieved. The long term funding for recruitment and renewal must be secured before a sustainable development of Chemical Engineering towards new strategic goals can be achieved. Similarly, the very unsatisfactory gender structure of Chemical Engineering, which prevents the UoA to take proper advantage of female talent, must also be addressed as soon as possible.

Finally, cooperative opportunities within KTH must be used better in several chemical fields, as well as in theoretical and practical modelling. In particular, interesting opportunities for renewal may be found through internal partnerships at KTH targeting biotechnology (enzymes), a research field that is of considerable interest within the other UoAs in the chemical area.

Strategy

The main strategic direction of the UoA towards renewable energy and sustainable environment is, in several ways, well chosen. Among others, it is of great societal importance and relevance, and it is clear that this importance will grow in the future. The strategy is good with real potential to achieve. Chemical Engineering has an opportunity to provide unique solutions to related industrial challenges and needs. The continuous upgrading, extension and advanced application of the generic chemical engineering tools is of outmost importance.

However, it is vital to select, prioritize, and focus on the research directions that have the highest potential. The most promising future areas seem to include sustainable energy supply, carbon dioxide remediation, new materials, green (environmental) technologies, clean water supply, food production, pharmaceuticals, and alternative novel automotive drivelines.

Among the research areas of particular strength in the UoA, some are well suited for work in the fields above. These include work on:

- Solutions for even higher energy efficiency in the transport sector, including a strong focus on biomass-derived fuels.
- Utilization of the extensive knowledge within gasification and heterogeneous catalysis, including modern catalyst preparation, for various combustion processes, and for fuel production processes in energy conversion systems.

Finally, the challenges and problems within the pharmaceutical industry call for efficient and interdisciplinary research, with the participation of chemists, chemical engineers, material scientists, and biochemists. Separation technologies, including crystallization and advanced chemical and enzymatic catalysis, are likely to be important fields, also in the future.
In conclusion, the Chemical Engineering UoA has a strong position in its research field in Sweden. The Unit possesses a wide variety of chemical engineering tools, a broad theoretical expertise, and a good know-how of advanced application of those tools, which are highly appreciated by industry. This has contributed to the considerable amount of external funding received. However, the present situation is not sustainable in the longer term, and needs distinct corrective action.

New recruitment in selected, priority key areas must be made to correct the unsatisfactory age structure and, at the same time ring in new research visions. A major effort must also be made to improve the unsatisfactory gender balance. This will require long term funding for recruitment to new and competitive research positions, but the opportunity to establish a strong chemical and biochemical engineering activity must be assessed and, if feasible, carried out.

Future Risks

Unfortunately, there is no guarantee that the present productive situation in the four UoAs will remain as it is. There are several risks. First of all, the research activities are to a very large extent based and directed by the availability of external support, since core funding from KTH is quite limited. While it is positive that substantial external research funding is available in Sweden, it also involves some risks, for example:

- “Pedestrian” research activities may in some cases be preferred to more exciting, but also more “risky” ones.
- The recruitment of outstanding young researchers as replacements for retiring staff is often difficult, partly because the job security at this level is unreasonably low.
- The infrastructure, including routine instruments, instruments for student laboratories, etc., may suffer since it cannot be maintained through external research grants.
- At times, obvious opportunities for productive research cooperation within KTH have not been used, since the chance of obtaining a grant was better when the applicants came from different universities, illustrating the over-dependence on outside grants.

Other risks in some UoAs are the unbalanced age distribution, an unsatisfactory gender balance, and a tradition for inbreeding. It is quite common that bright undergraduate students continue as PhD students and eventually obtain a position in the same UoA. This is not a healthy situation: KTH needs new inspiration as much as the young researchers do. Since a

similar situation exists at other Swedish universities, it may be a task, not only for KTH, but also for government to improve the mobility in Swedish research.

Finally, as a very recent development, the Swedish Government has decided to demand fees from student from outside the EU. This may strongly reduce the present opportunities for attracting outstanding students, e.g. from China.