“WHY PURSUE RESEARCH PROJECTS IN AN ACADEMIC ENVIRONMENT?”

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September 2013

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Inaugural lecture delivered on 03 September 2013

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Editor: SU Language Centre
Printing: SUN MeDIA
ISBN: 978-0-7972-1453-8

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CAREER SUMMARY

2012–present	**Professor in Chemical Engineering** Department of Process Engineering, Stellenbosch University, Western Cape, South Africa
2008–2012	**Associate Professor** Department of Process Engineering, Stellenbosch University, Western Cape, South Africa
2002–2008	**Senior Lecturer** Department of Process Engineering, Stellenbosch University, Western Cape, South Africa

UNIVERSITY EDUCATION

Business Management	**Stellenbosch University,** 2003–2005
January 2003–December 2005	**Part-time MBA, awarded December 2005** ***cum laude***; specialisation in project management, consulting and technology start-ups

Engineering	**Stellenbosch University**, 1993–2002
April 2003	**PhD (Chemical Engineering)**
March 1999	**MScEng (Chemical Engineering)** ***cum laude***
December 1996	**BEng (Chemical Engineering)** ***cum laude***

RESEARCH EXPERIENCE

Act as Associate Director in the Research Chair in Liquid Biofuels (CoER; www.sun.ac.za/biofuels) and is associated with the Centre for Renewable and Sustainable Energy Studies (www.sun.ac.za/crses), both at Stellenbosch University. Supervised a group of approximately 30 researchers in biomass processing and biotechnology.

Completed and ongoing research projects:

Biochemical conversion of biomass into bioethanol as biofuel

- Convert paper sludge from wood pulping or paper recycling into ethanol with Paper Manufacturers of South Africa (PAMSA), including Sappi, Nampak, Mondi, MPact and Kimberley-Clarke (2010 to present; ongoing).
- Develop high-biomass sugarcane cultivars with improved fibre characteristics for pretreatment-hydrolysis-fermentation into ethanol (2009–2013).
- Screen and select sweet sorghum and triticale cultivars for cellulosic ethanol production, and demonstrate the technical and economic impact on scale-up and final production plant design through process modelling (2009–2013).
- Perform pre-feasibility assessment of triticale grain conversion into ethanol in the Western Cape. Do experimental tests on starch and bran hydrolysis-fermentation. Carry out economic modelling of process scenarios using stochastic (Monte Carlo) methods (2009–2011).
- Perform integration of cellulosic ethanol from sugarcane bagasse with sugar syrup fermentation in an integrated production plant (2011 to present).

Thermochemical processing of biomass, including pyrolysis and cogasification
Modelling of biorefineries for coproduction of fuels and chemicals from biomass

COMMERCIAL AND BUSINESS EXPERIENCE

- Act as Director: Industrial Processes at SBMT since 2010. Perform technology transfer from Mascoma Corp.
- Perform mass and energy balance evaluation on commercial pyrolysis technology (Thermex, 2010).
- Perform techno-economic evaluation of opportunities for electricity production from biomass (ZZ2 farming, 2011).
- Investigate woody biomass supply and drive upgrading for cofiring with coal in electricity supply (CSIR, ESKOM, 2011–2012).
- Work as associate of InnovUS, Stellenbosch University IP commercialisation office, which involves patent protection, investment decisions and IP commercialisation agreements (2006–2009).

RESEARCH RECORD

Have had 53 international, peer-reviewed articles published in scientific journals in the fields of biomass processing and biotechnology.

Have supervised 8 PhD dissertations and 22 MSc theses to completion, resulting in postgraduate qualifications for the candidates concerned.

Presents an annual short course in bio-energy to postgraduate students and industry representatives, in collaboration with the Centre for Renewable and Sustainable Energy Studies at Stellenbosch University (www.sun.ac.za/crses). This course is based on the candidate's research activities in the Research Chair for Liquid Biofuels.

WHY PURSUE RESEARCH PROJECTS IN AN ACADEMIC ENVIRONMENT?

The pursuit of academic research is internationally considered to be a key deliverable of academic careers, with ever-increasing expectations of demonstrated research capacity and outputs as a means to substantiate academic excellence. The motivation behind granting such priority to research in the academic environment warrants careful consideration, considering the amount of time, effort and funding invested in these activities. Such consideration is the goal of the present essay, with particular application to the engineering and scientific domains of academic research.

1. THE PRESENT-DAY ACADEMIC RESEARCH ENVIRONMENT

The majority of academic research projects are carried out with academic goals in mind, as is generally expected in the university environment. These academic goals include providing student training, producing scientific publications and receiving recognition for academic excellence, as I will now describe in greater detail.

For many decades, *student training* by itself has been the primary reason for the undertaking of academic research projects. In an era when an academic publication record was not considered essential, providing a student with the opportunity to perform research in a particular field, to write a thesis or dissertation and to complete the final examination was the true end goal. The research project served as a vehicle for the student or candidate to demonstrate a set of academic skills, and assessment of whether such skills had been gained was the key outcome of the process.

Globally speaking, this era has been superseded by the concepts of 'publish or perish' and 'unpublished work does not exist', indicating the *pre-eminence accorded to publication of research outputs in international scientific journals*. Such peer-reviewed publications are a key component of career development for an academic researcher and serve to demonstrate proficiency in research; writing an excellent paper published in a top scientific journal has become a major driver of much research undertaken in the academic world. Such publication of results has gained importance in the graduation of postgraduate students, especially PhD candidates, who must demonstrate that research outputs from their dissertation can 'hold their own' in the domain of peer-reviewed publications. Many universities around the world require PhD candidates to produce a minimum number of accepted publications before their final examination.

Both student training (graduations) and publication have become significantly more important as a means of drawing funding for academic research. South African Universities face increasing financial pressures due to decreasing subsidies; therefore, increasing the number of degrees and publications in order to earn more subsidies will be an ever-growing factor in the financial survival of universities.

Journal publications also contribute significantly to gaining recognition for *scientific or research excellence,* which is a key motivation for academic research work. Academic research groups, departments, faculties and universities are globally assessed for academic excellence according to the number and significance (in an academic sense) of publications produced. This cultivated various evaluation systems and rankings of academic research effort, which provide a ladder for academic researchers to climb; perhaps only the Nobel Prize has remained as one of the top measures of academic excellence. Such pursuit of academic excellence may create a self-serving system in which accumulation of scientific knowledge and demonstration of expertise by means of a long and illustrious curriculum vitae become goals in themselves.

Demonstration of accumulated academic knowledge can therefore become the end goal, both as regards career development and financial survival. The question is whether the effort, time and financing applied in such a pursuit is truly applied in the best interest of the society or economy that funds such activities. Should postgraduate student training be undertaken in research fields and areas that have little chance of impacting the world outside of academic research? Should academic research be expected to impact the world of industrial, economic and societal activities in a meaningful and significant manner? Is academic knowledge gained through research projects with no potential for near-term application in the 'real world' of any value? Specifically in the engineering environment the emphasis is supposed to be on gaining knowledge that has direct relevance for the industry, but can such a research focus be accommodated in the academic environment and systems?

Unfortunately, the continuing emphasis on purely academic output and the financial systems that apply to academic research provide little flexibility in this regard. We should carefully consider this emphasis and these financial systems to determine whether they function as enablers or impediments for the academic environment to deliver research outputs that impact on the real world.

2. THE SYSTEM OF ACADEMIC RESEARCH FUNDING

Funding of academic research is a complex and challenging domain for any researcher. Researchers used to receive a guaranteed budget and access to funding to pursue research projects, but this is no longer the case. In the scientific, engineering and health sciences, the completion of academic research and postgraduate training of students have become largely, almost exclusively, dependent on funding from outside of the university. Academics spend much of their time writing proposals for a complex system of local and international funding opportunities, and compete with other groups for access to such funding – a systems that requires an excellent publication track record and scientific or industrial networks.

There are virtually no opportunities for postgraduate student training in the scientific, engineering and health sciences faculties without such external funding, due to the high cost of development work and the expectation that postgraduates must have a demonstrated source of financial support. Most postgraduate students can only pursue postgraduate studies with the aid of bursary or scholarship funding, a large portion of which is provided by the research group itself. Training a master's student in the engineering environment can easily cost more than R250 000 per student, while investing R1 million of external funding in the training of one PhD student is not uncommon. The extent of external funding required for postgraduate student training is not widely recognised and is often underestimated.

The system of research funding has therefore become a goal in itself of academic research, especially considering the increasing importance of both external funding and subsidies earned through research outputs in the financial survival of universities. These days, academic research performance at universities is assessed primarily with reference to financial measures, of which external research funding and subsidies, and the contribution of both to university operational budgets, have become the most important considerations. External funding is expected to provide an ever-increasing portion of universities' operational budgets, to the point where the expectation is of 'full cost recovery for postgraduate student training'. In other words, the university should gain subsidies from postgraduate student graduations and publications without having invested in their actual cost of training. Less than 10% of subsidies earned through graduations and publication are invested in the operational costs of postgraduate student training, with the latter remaining primarily dependent on external funding.

The system of academic research funding requires a research group or an academic to 'find a unique space to occupy', 'ensure that you maintain an advantage relative to other groups in this space' and 'perpetuate the availability of research funding from a particular source for as long as is possible'. In short, academic research and career development for academic researchers do not exist without accessing and securing an external source of funding. Furthermore, most funding is secured for three years or less at a time, requiring a continual effort to secure research funding, the single biggest issue in building an academic research career. Academic research funding has evolved into a complex system of multiple minor contributions, negotiations around individual projects and management of multiple researchers and students; each source of funding is associated with its own set of deliverables, which should be combined with the overall goals of producing academic research outputs (student training and publication). This complex system eventually requires more time for management than for performing the technical research itself.

3. SHOULD ACADEMIC RESEARCH IMPACT THE WORLD OUTSIDE OF THE ACADEMIC PARADIGM?

The concept of academic research targeted at industrial, economic and societal benefit is receiving increased attention. The state of technological development and the commercial advantages of advanced technologies in today's markets provide a strong motivation for academic research to focus on actual problems and solutions for the world outside of academic outputs. The world is growing ever more complex from a systems and technology point of view, requiring not only technical expertise in areas required for economic advancement but also technical solutions for implementation.

The latter represents a paradigm shift in most academic departments and research groups, not only in South Africa but also on a global scale. The importance of this paradigm change lies in the realisation that academic research for the purpose of academic outputs alone cannot be afforded in a country where technical outputs and human capital with expertise to implement such outputs are sorely required for advancement of global competitiveness. Technological advancement has become a critical component of economic development and maintenance of global economic leadership in the developed world, where investment in science and technology is considered as essential. In the developing world, there is no equal recognition of own development activities; instead, there is a focus on 'buying the best technology' and thus maintaining economic dependence on the developed world. This situation is projected to develop into a scenario where the 'developed world' will be replaced by 'those that have intellectual property (IP),' and will be distinguished from those that 'buy IP from elsewhere', in other words the present-day 'developing world'. Countries such as South Africa lag far behind as regards not only the number of engineers or scientists and trained postgraduate students, but also the training of students in areas that are economically important, the development and application of new technologies and the growing of advanced industries to provide jobs for such graduates; supply and demand of human resources require considerable reorganisation. Many South African companies cannot afford in-house departments for research and development; consequently, they expect to have access to research expertise at universities that will provide real-world solutions.

A number of paradigm changes will be required for academic research to deliver outputs that primarily meet the needs of industry and society rather than the immediate concerns of maximising research sponsorship, graduations and publications as a means of financial survival. Firstly, there is the recognition that scientific and technical skills applied within a purely academic environment are equally applicable outside of the academic environment; accumulation of knowledge should give eminence to the practical implementation of such knowledge. As an example, industrial implementation of new technologies often fails because first principles, well known to academics, are not applied correctly. Secondly, it requires a refocus of research attention on actual industrial problems and opportunities rather than selection of research projects based on what is 'technically comfortable' within the academic domain. Innovation and creativity to find real-world solutions require a paradigm shift to application of scientific and technical excellence to a real problem or opportunity.

Unfortunately, there are also several impediments to such a paradigm shift to real-world innovations by academic research. Firstly, the expectation remains for academic research to contribute an increasing portion of the operational budget of the university, which requires academics to focus on securing funding, student training and publications. Marrying a real-world focus and projects with those that deliver academic outputs is by no means a trivial matter, since many industrial problems require solutions that do not fit within the regime of academic research outputs.

Furthermore, research projects should be performed for the sake of finding solutions that can be implemented rather than as a means to secure funding and academic outputs, which is often the true purpose. Funding of research is a system and project of its own and detracts significantly from the actual research work to be performed. Basic research in South Africa remains largely underfunded, with many groups not being able to afford a shift in focus to real-world problems. Furthermore, the scale-up and demonstration of new technologies, as a critical and essential part of technology development, does not attract much funding, partly because it is expensive and partly because it is often too early to attract private investment, leaving many innovations to die in the laboratory.

Access to information on industrial or economic problems and opportunities is also an impediment to research projects that will deliver real-world impact. Many models for commercialisation of academic research imply that academics will 'discover' and 'innovate' real-world solutions from within the experiences gained in academic research. However, in reality very few such opportunities exist outside of a highly connected world of technological complexity and industrial exposure. Companies spend as much effort finding out what to produce or deliver as they do actually developing the product or service. Without exposure to real-world problems or opportunities, academics have very little opportunity to propose or develop real-world solutions.

(Un)fortunately, the best commercial opportunities and ideas are kept secret as part of the competitive advantage of companies and therefore are excluded from projects and funding processes in which academics can participate.

Without access to the latter industrial and economic information, much time is spent in academics on projects and solutions that have no chance of being implemented in the real world. Many ideas that seem to be academically excellent simply have no chance of survival in the economic domain, based on the starting point and (academic) end goals defined at project initiation. Many academic projects are selected purely based on 'technical comfort zone' with no relevance to the real world and can be perpetuated indefinitely, provided that research funding remains available. In such cases, research projects continue to be undertaken purely for the sake of accumulating knowledge and research outputs without consideration for their relevance to the real world. Thus, academics can become a self-serving system.

An external impediment to technological innovations and implementation from academic research is the readiness of local markets. There is the perception in many academic research groups that implementation could be 10 to 20 years away and that spending a lifetime on academic research with implementation by the next generation of researchers is a worthy cause. This is, however, a highly risky proposition; working on problems and solutions that are so far away also means that the probability of no implementation is very large, and in the meantime many problems or opportunities that are more immediate remain unresolved. Such long-term investments in academic research are therefore done primarily based on a comfortable technical or scientific domain rather than consideration of benefits outside of the academic world. Many academics do find the real world to be unnecessarily complex and uncontrolled, an experimental setup where you have no chance of controlling all the inputs.

It remains true that finding a research problem to work on that will produce an 'academically interesting output' is significantly easier than defining and solving a technical problem outside of the academic world. Defining a problem that lies well within one's field of expertise, with a successful outcome being fairly certain from the outset, represents a much less risky proposition for a postgraduate student project, with neither student graduation nor academic publication outputs being risked or compromised. To the detriment of funders and society, risk aversion and focus on short-term financial gains result in many clever people spending much of their professional efforts on projects that do not pursue solutions to real-world problems. In the scientific, engineering and health fields, there is an ample supply of real-world problems to address; developing expertise and training students in technical fields that can find such solutions should be the goal of postgraduate research.

4. REDEFINING THE ACADEMIC RESEARCH PARADIGM WITH AN OUTWARD FOCUS

There remains therefore the need for redefinition of the academic training and research paradigm, to serve primarily as an asset in economic development rather than as a means of financial survival of research groups and universities. Both industry and society at large stand to benefit from such a system, together with postgraduate students being provided with expertise to resolve real-world problems. Both economic and social development in South Africa remain dependent on such 'export' of real-world solutions from academic research.

Some progress has been made in this regard. Stellenbosch University has defined and supported the HOPE Project as a means to draw academic research and projects closer to the real world of socio-economic needs. Furthermore, several opportunities for industry collaboration in research projects remain. Such examples of projects require proactive discussion, network building and joint project definition, with industries providing exposure to real-world problems and opportunities, and academics providing technical expertise and vision of future technology potential. The benefit of this approach to research definition is that it avoids a situation where academic research is performed purely for the sake of academic outputs by themselves. However, academic outputs remain as a dominant output in such projects, which could limit the potential for implementation of technical solutions. For example, why should academics in the engineering domain not have opportunity to design and build commercial plants, considering that they propose to teach students to do the same? The system of academic research often expects academics to focus on 'early-stage' research and academic outputs without recognition or rewards for activities that directly support industrial implementation and economic development, despite the evident loss of opportunity to industry and society. The lack of flexibility in funding of academic research and expected (financial or academic) outputs from research therefore detract from real-world implementation of solutions. Many academics are simply not drawn to such implementation projects as such projects are perceived to fall outside of supported activities and expected deliverables.

Academic research, especially in the engineering domain, should aim to address industrial, economic and social problems or opportunities first before aiming for student graduations and publications. This requires a greater commitment to industry-based research, especially in areas where the industry remains technically weak, which requires a greater contribution to implementation from academic research but also has potential for significant job creation and economic development.

Such a focus requires prioritising of scientific and technical expertise in areas that do have relevance to industrial activity, while also requiring an intimate knowledge of industrial challenges and opportunities. In short, it requires academics to step outside of a purely academic domain and seek opportunities to engage with industry, to understand and commit to industrial problems and to deliver significant value to industrial partners as a greater priority than seeking immediate benefits of student graduation and publications. Unfortunately, the primary aim of many academic research projects is to secure research funding for students and publications. There is no significant commitment to the reality of real-world impacts from academic research, simply because in South Africa there are so few examples of where this has been done successfully. Irrelevance to real-world problems for the benefit of academic outputs is perhaps not the most fruitful application of research experts.

Such a shift in paradigm also requires a different approach to research and university financing. The extreme focus on outside funding and subsidies as a means of financial survival in itself produces and environment that is not conducive to seeking solutions to real-world problems. Continued increases in the overhead costs that are subtracted from external research funding will also increase the amount of time that academics spend on securing funding, as opposed to seeking real-world solutions.

5. THE PROCESSING OF PLANT BIOMASS INTO MATERIALS, CHEMICALS AND FUELS AS ECONOMIC OPPORTUNITY

Some examples of research projects aimed at industrial problems and opportunities can be provided from the work of the research group at Process Engineering, although by no means being able to show industrial implementation of research outputs.

Plant biomass represents the only renewable source of carbon available to humankind and is therefore widely considered to be a future replacement for fossil fuels such as coal, oil and natural gas. Plant biomass is produced in nature by the conversion of atmospheric CO_2 into the chemical structures of plant material through the process of photosynthesis. This provides potential for significant savings in greenhouse gas emissions compared to fossil fuels in providing the same chemicals, materials and energy services to society. Conversely, there is no significant and ongoing formation of fossil fuels, implying a finite (though very large) resource, and there are increasing atmospheric emissions from their utilisation, as seen in the rise in atmospheric levels of CO_2 over the past decades.

Several large industrial processes have been in operation for many centuries using plant materials as feedstock. These include the production of sugar from sugarcane and sugar beet, the processing of grains through dry and wet milling into a range of food-related products, and the pulping of woody plant biomass for paper production. The scale of many of these industries matches that of commercial fossil fuel-based activities, thus giving rise to the concept of a 'biorefinery' that will replace fossil-based products with those from renewable plant biomass. Processing of plant biomass can also be incorporated into existing industrial facilities that utilise fossil fuels as a means to reduce the environmental footprints of such industries. Some examples include the replacement of part of the fossil fuels used in the production of electricity and liquid transport fuels from coal and natural gas, the use of coal as a source of industrial heating and the conversion of mineral ores into metals through smelting operations.

The source and method of production of plant biomass remain critical to achieving the environmental and societal goals of replacing fossil fuels. Plant biomass available to humankind should be applied in a hierarchy according to the priority of human needs. In this scheme, the most important application is considered to be human food, followed by animal feed, the production of materials and chemicals and, finally, bioenergy. The production of biomass for materials, chemicals and energy purposes should therefore not compromise the availability and application of biomass for human needs being given greater priority in the hierarchy. For the purposes of materials, chemicals and energy production, priority should rather be given to waste from processes and products with greater priority, such as harvesting residues from agriculture, presently left on the land or burnt for disposal, waste cooking oil, green waste going to landfill, and so forth. The role of dedicated 'energy crops' in the production of energy, chemicals and materials remains widely debated in the context of sustainability, with key issues centring on the extent to which the efficiency of biomass production on existing agricultural lands can be improved to such an extent as to provide for all of the potential applications of plant biomass within the hierarchy.

Research projects in this field have aimed to optimise processes for the conversion of plant biomass as a means to maximise the economic and environmental benefits derived. The production of energy products such as biofuels from plant biomass has been given priority in governmental policies and research funding sources, purely by analogy with renewable energy production from solar and wind sources. There is a gradual recognition that application of available plant biomass to chemicals and materials can provide similar environmental benefits as energy production, although with much-improved economic benefits, as a driver for commercial implementation. Completed research projects have addressed implementation of biomaterials (biopolymers) and bioenergy into sugarcane processing, petrochemical processes and paper-and-pulp industries. Projects have also been completed in conjunction with research groups working on the development of new 'energy crops', aimed at maximising renewable carbon yields per hectare of cultivated land. Furthermore, processing of grain products into beverage-grade ethanol and biofuels has also been investigated with industrial partners. Examples of research papers are provided as attachments, demonstrating the combination between laboratory-scale process development and the application of modelling tools to assess commercial viability and relevance of such technologies.

The future of research in this field work lies in the scale-up of preferred processes for plant biomass conversion to demonstration scale, as a means to prepare technologies for commercial implementation, and a greater emphasis on the production of chemicals and biomaterials from available plant biomasses. Much of the work performed to date has demonstrated the limitations in realising commercial opportunities for fossil fuel replacement by plant biomass; many idealistic approaches in academic research have no viability in the commercial world. I seek a paradigm of academic research that is not confined to such approaches.

6. SELECTED PUBLICATIONS

Amigun B, JF Görgens, JH Knoetze (2010). Biomethanol production from gasification of non-woody plants in South Africa: Optimum scale and economic performance. Energy Policy 38: 312–322.

Amigun B, D Petrie, JF Görgens (2011). Economic risk assessment of advanced process technologies for bioethanol production in South Africa: Monte Carlo analysis. Renewable Energy 36 (11): 3178–3186.

Carrier M, AG Hardie, Ü Uras, J Görgens, JH Knoetze (2012). Production of char from vacuum pyrolysis of South-African sugar cane bagasse and its characterization as activated carbon and biochar. Journal of Analytical and Applied Pyrolysis 96: 24–32.

Chimphango AFA, WH van Zyl, JF Görgens (2012). Isolation, characterisation and enzymatic modification of water soluble xylans from Eucalyptus grandis wood and sugarcane bagasse. Journal of Chemical Technology and Biotechnology 87 (10): 1419–1429.

Diedericks D, E van Rensburg, JF Görgens (2012). Fractionation of sugarcane bagasse using a combined process of dilute acid and ionic liquid treatments. Applied Biochemistry and Biotechnology 167 (7): 1921–1937.

Leibbrandt NH, AO Aboyade, JH Knoetze, JF Görgens (2013). Process efficiency of biofuel production via gasification and Fischer-Tropsch synthesis. Fuel 109 :484–492.

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Van der Merwe AB, H Cheng, J Görgens, JH Knoetze (2013). Comparison of energy efficiency and economics of process designs for biobutanol production from sugarcane molasses. Fuel 105: 451–458.

Vena PF, MP García-Aparicio, M Brienzo, JF Görgens, T Rypstra (2013). Effect of alkaline hemicelluloses extraction on kraft pulp fibres from Eucalyptus grandis. Journal of Wood Chemistry and Technology 33 (3): 157–173.