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Response to the Senate Inquiry

The shortage of engineering and related employment skills

on behalf of the
Australian Council of Engineering Deans Inc.

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SUMMARY

The Australian Council of Engineering Deans Inc. (ACED) comprises the leaders of Australia's university-based engineering faculties and schools. ACED's mission is to support engineering education and research in Australia's higher education sector, and has members from 33 universities. ACED is a member of the Australian National Engineering Taskforce (ANET) consortium.

This submission addresses **educational issues** that are critical to reducing the engineering skills shortage, particularly in the medium and long term, since the educational process through university to degree qualification and **independent practice** takes many years. Although education falls outside the explicit terms of reference (ToR), having strong education pathways to the qualifications for **entry** into engineering occupations is **absolutely essential** to any sustainable engineering workforce strategy. Universities are the sole supplier of Australian graduates into the professional engineer occupation, and share responsibility with TAFE institutions for education of engineering technologists and engineering associates (known internationally as engineering technicians).

In 2010, ACED members awarded accredited qualifications for entry to these occupations to approximately 10,000 graduates, principally Bachelor of Engineering degrees. Approximately 35% of these awards were made to international students, and there is anecdotal evidence that many of these graduates would wish to join the Australian engineering workforce. Strategies to grow graduate numbers are directly relevant to ToR (e) on "*effective strategies to develop and retain engineering talent in the private and public sectors ...* "

The universities also awarded approximately 4,500 postgraduate coursework qualifications and nearly 1,000 postgraduate research degrees (approximately 50% to international students in both categories). One must reasonably assume that most of these graduates have gained these postgraduate qualifications to enhance their employability in the Australian or international engineering workforce. A small number of these are mid-career scientists retraining for engineering. Some postgraduates are supported directly or indirectly by industry. Increasing postgraduate numbers may require action on ToR (f) in providing further: "*incentives ... for skills development*". ACED would welcome a collaborative approach to action in this area, noting that the higher education sector can deliver education and skills through short courses as well as formal awards.

This submission presents evidence on the contributions that the university engineering system is making in producing qualified engineers for industry, and supporting working engineers, and the constraints in the system. To produce more engineering graduates at all levels, and address other related matters, ACED makes seven recommendations to inform policy development:

(i) The number of school students taking higher levels of mathematics and physical sciences in their secondary certificate must be increased, to underpin growth in all of the engineering qualifications offered by the higher education sector. Every effort must be taken to lift the persistently low participation rates of women (less than 15% in undergraduate programs) and of indigenous students.

(ii) The school curriculum in mathematics, science and other areas should be enhanced by demonstrating stronger connections between these areas and engineering. The opportunities offered by engineering study and careers should be more strongly promoted. Part of the solution here may lie in enhancing teacher education courses, or providing in-service training through the associations for science, mathematics and design & technology teachers.

(iii) Mid-career entry to accredited engineering qualifications is relatively rare, although several universities are operating accredited masters degrees at professional engineer level for such

purposes. Incentives and funding mechanisms to encourage expansion of numbers of qualified engineers for all levels deserve further consideration.

(iv) University engineering faculties and schools, and engineering industry, should be encouraged to engage more closely to advise on curriculum development, provide case-study and project development, in-industry visits, structured training and scholarships, joint appointments, etc., to enhance the quality of the engineering programs and the graduates' employability skills.

(v) Engineering industry groups should be encouraged to work together with the university sector to provide short-course or award programs in key advanced topics in high demand for practicing engineers.

(vi) Industry and the profession need to consider how the currently under-used occupational role and career of Engineering Technologist can be more positively promoted within Australian industry, and thence to prospective students. In the long term, a more balanced workforce would reduce the costs of engineering services and education.

(vii) Industry groups, the profession, and educational providers and regulators need to examine how qualifications for Engineering Associates can be optimally formulated and delivered by university and VET providers in the locations and for areas of practice where there is high demand for these qualifications.

Much of the evidence presented in the following sections has been formulated in studies undertaken by ACED and partners in recent years (King, 2008, Godfrey & King, 2011, King, et al., 2011). The full reports are available to the Senate Committee.

Senior members of the ACED Executive would welcome the opportunity to present to the Committee in person.

BACKGROUND: Engineering enterprise is transformational and global

Australia is not alone in identifying skills shortages in engineering occupations. As a result, topics around the supply, quality and development of university engineering education have been the subject of numerous reports in Australia and overseas during the past few decades. These decades have also seen economic and societal transformations through torrents of engineering enterprise and technological innovation. Whilst engineering innovation is global, areas in which Australian engineers have made significant contributions include:

- phenomenal increases of labour and capital productivity, quality improvements and safety in the resources and manufacturing sectors;
- medical and health services underpinned by new imaging techniques and instruments, and the invention of remarkable prosthetic and assistive devices;
- ubiquitous growth of computing and information technologies that have spawned the internet and its application to all facets of modern life in ways unforeseen by the inventors of the original underpinning technologies.

Global technological advances appear to have led society at large to expect engineered products, systems and infrastructure to be reliable and effective, while improvements in functionality and performance are contained in terms of price. On the whole, the engineers who design and construct manufactured products (including motor vehicles and ICT devices and systems) continue to satisfy these demands. The products are invariably outcomes of the private sector, with design and

manufacturing expertise and costs optimised globally. The evidence from Australia is that manufacturing companies, most of which are small, will tend to devote their training budgets to specific technologies and workplace matters, and operate with the expectation that they can induct newly qualified professional engineers, technologists and technicians reasonably quickly. The companies may also draw on publicly funded basic and applied research for their technological advances and subsequent commercial success. The Cooperative Research Centre program in Australia can be regarded as successful in this respect.

Major engineering companies involved in infrastructure development and renewal also operate globally and optimise their services accordingly. Invariably, they competitively contract their services in design and construction to governments and other commercial organisations. Many companies provide good graduate induction and development schemes. These schemes, and others, including the professional development program operated by Engineers Australia (EA, 2012), preserve the best principles of the pre-1990s era of government-based engineering utilities for electricity generation and distribution, telecommunications, water and sewerage, and road and rail infrastructure. Nevertheless, in the global environment of contract-based engineering services, and price-based competition, Australian companies will tend to seek to employ experienced personnel **from wherever they can be sourced**, and minimise training costs. One result of these imperatives is that there can simultaneously be high levels of graduate unemployment and shortages of engineers. We return to this point later.

ENGINEERING QUALIFICATIONS – GRADUATE NUMBERS

Australian universities provide awards from AQF Level 5 Diplomas to AQF Level 10 Doctorates. Table 1 summarises the principal qualifications and the numbers of graduates at each level in 2010, and shows how they relate to the three defined occupations of professional engineer, engineering technologist and engineering associate (engineering technician).

Table 1 Qualifications in engineering offered in Australian universities, with 2010 graduate numbers

AQF Level	qualification	accredited engineering occupations: entry level qualification	graduates (2010)	
			domestic	international
10	PhD		474	318
9	Masters by Research		99	97
9	Masters by Coursework	some Master of Engineering programs accredited for Professional Engineers	1,024	2,660
8	Other postgraduate		672	279
7 - 8	Bachelors Degrees (including 3-year, 4-year and Honours)	4-year post-school Bachelor of Engineering for Professional Engineers 3-year post-school Bachelor of Engineering Technology for Engineering Technologists	5,692 452	2,601 395
6	Associate Degree Advanced Diploma	2-year post-school qualification for Engineering Associates (or pathways to further study)	320	94
5	Diploma	(pathway and enabling qualifications)	109	295
		Total awards	**8,935**	**6,655**

Data: DEEWR Higher Education Statistics Unit

Qualifications to commence supervised practice in these occupations are formally accredited by the professional body, Engineers Australia, in an internationally benchmarked system of mutual recognition of substantial equivalence (IEA, 2009). In addition, the VET sector provides Levels 5 and 6 Diplomas and Advanced Diplomas, as well as Level 3 Trades Certificates. A small number of VET Advanced Diplomas are accredited at the engineering associate level.

Program changes made by the universities (including the Melbourne and UWA "3 + 2" models) and positive enrolment trends will result in increasing numbers of domestic students graduating from Bachelors of Engineering (BEng), accredited Master of Engineering degree awards, and accredited Associate Degrees. Enrolment trends indicate that there will be fewer future graduates from 3-year Bachelor of Engineering Technology (BEngTech) degrees.

Recent research (King, *et al*., 2011) undertaken for the Australian National Engineering Taskforce (ANET) has found that most students who enrol in BEngTech and Associate Degrees aim to use these qualifications as pathways to a B.Eng. degree. Whilst such aspirations are creditable, they also undermine the standing and value of the engineering technologist and engineering associate occupations, and thus may exacerbate some areas of skills shortage. This research also reported relatively low numbers of domestic completions from VET awards at AQF levels 5 and 6, being 1,523 and 1,773 respectively in 2008. There was also found to be very limited provision of these awards in areas of civil engineering and construction in parts of Australia that have major infrastructure growth. These number imbalances and pathways issues were discussed further in a meeting held in Sydney (1 Dec 2011) convened by Skills Australia.

Australia differs from many other countries in having what *de facto* amounts to only one widely recognised "engineering" degree qualification, the four-year Bachelor of Engineering professional engineering degree and its five-year equivalents. Other countries, such as Ireland, Canada, USA, South Africa and Germany, have more clearly differentiated their professional engineering qualification and occupational standards from those of the engineering technologist. There is a trend towards 5-year professional engineering degrees in both Australia and overseas.

The 2008 review of engineering education (King, 2008) reported respondents' observations that much of the work undertaken by 4-year qualified graduates is actually at "engineering technologist" level. The impact of this can be negative for employed graduates who perceive their education and skills to be under-utilised and undervalued.

Policy considerations for long term change to the balance of engineering occupations and the corresponding educational pathways are addressed later in this submission.

THE SUPPLY OF STUDENTS INTO ENGINEERING EDUCATION PROGRAMS

DEEWR data, Figure 1, shows that domestic commencing enrolments in bachelors degrees (3-year and 4-year) in engineering have increased steadily since 2005, at a rate of about 5% per annum, to about 12,500 in 2010. Note that from 2009 the University of Melbourne has not admitted students into bachelor degrees in engineering: they mostly enrol in the Bachelor of Science. The "other undergraduate" category includes associate degrees, and diplomas and enabling programs. Clearly these numbers are increasing quite rapidly.

Engineering deans have reported that most of the domestic growth is in civil engineering, reflecting a reversal of the decline in that discipline prior to 2000, while electronics and computer engineering areas have declined.

International commencements, Figure 2, grew rapidly over the same period in most award categories. Numbers in both postgraduate coursework and higher degrees by research fell slightly between 2009 and 2010, probably due to the high $A, international competition, visa issues, and the apparently racist incidents in Melbourne. At least some of the bachelors degree commencement growth (to 6,626 in 2010) is in offshore campuses and partnerships of Australian universities. International enrolments form a large proportion of all commencing enrolments in engineering, about 37% since 2007, and more than 50% of research degree commencements.

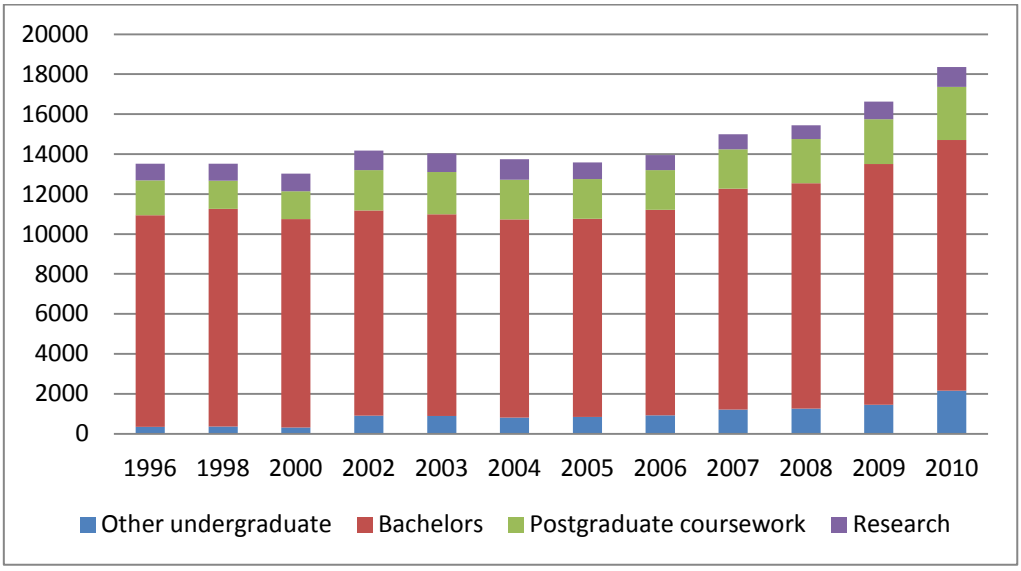

Figure 1 Domestic commencing enrolments into Engineering and Related Technologies, 1996 – 2010

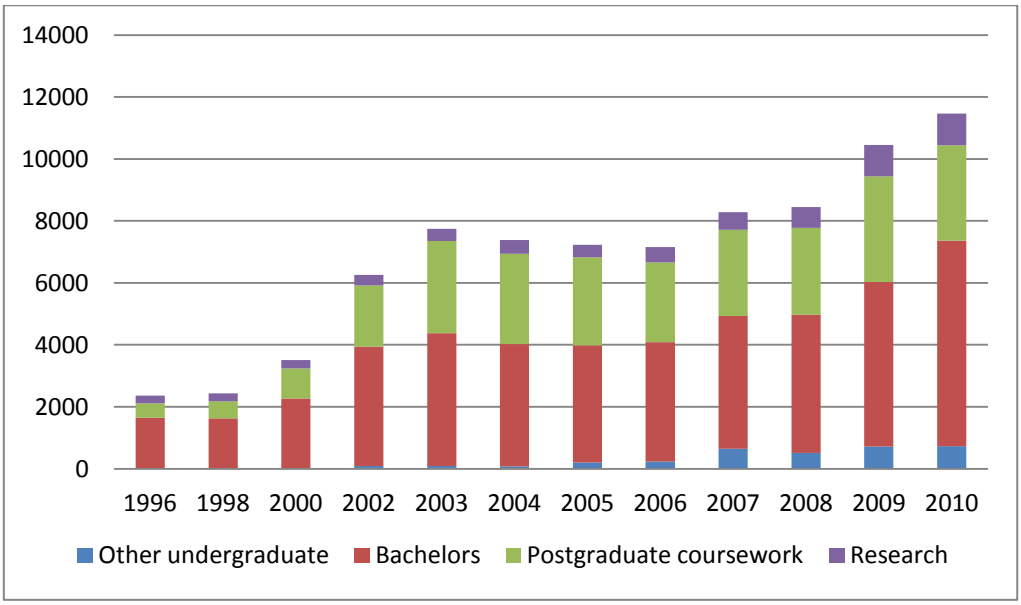

Figure 2 International commencing enrolments into Engineering and Related Technologies, 1996 – 2010

The participation of women, measured as commencing enrolments, in engineering in most award categories increased in the late 1990s. Aggregate participation rates are shown in Figure 3. Women constitute about 25% of research degree enrolments. The proportion of women in domestic bachelors enrolments has been around 14.4% since 2007. Indigenous commencements in this field of education are very low, leading to fewer than 20 graduates each year.

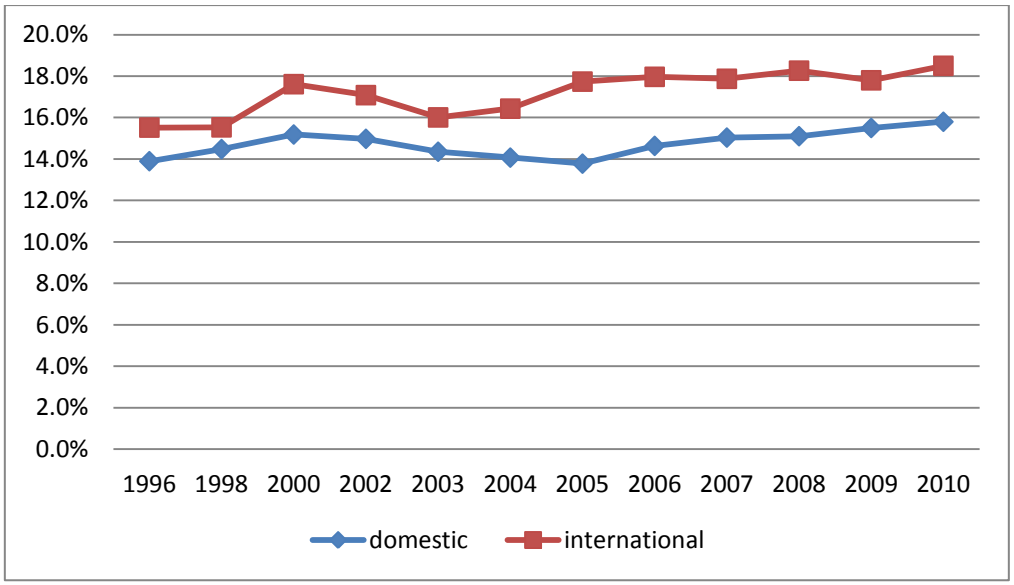

Figure 3. Participation rates (%) of women commencing award programs in Engineering and Related Technologies, 1996 – 2010

The detailed attrition study (Godfrey & King, 2011) carried out for ACED showed that about 65 - 70% of domestic students who commence an engineering bachelor degree are likely to graduate from it, some from a different institution than the one at which they commenced engineering study. (Such inter-institutional transfers depress apparent aggregated graduation rates.) The institutional graduation rate varies between institutions for a wide range of reasons. Institutions with high proportions of school leavers with high ATAR scores will have higher average BEng graduation rates than those that admit large numbers of mature-entry part-time employed students on the basis of TAFE qualifications. This attrition study made a number of recommendations to improve retention rates and to assist specific groups of students. The focus on increasing retention is being pursued currently in a five-university study led by the University of Southern Queensland on the use of online self-assessments to motivate first year engineering students to engage in and manage their learning. Specifically, this project aims to identify factors that predict successful transition to university life of engineering students, and to use this information to develop tools and strategies to enhance progression and graduation into the profession.

Across the system, the take-up of engineering places is limited by the supply of qualified and motivated students (school-leavers and mature-entrants). The increases in the numbers of students enrolling in Associate Degrees and foundation studies, and who subsequently qualify to transfer into bachelor degrees, indicates the willingness of some universities to expand the scope of their engineering enrolments.

For engineering graduation numbers to be increased rapidly and significantly, it is evident that more school leavers will need to be motivated towards engineering. They will need to have studied mathematics and science to appropriately advanced levels in their school certificates. The trends in

mathematics and physics subject enrolments have tended to be in the opposite direction (Barrington, 2006; Ainley et al, 2008), and engineering faculties have to some extent compensated for this by introducing foundation, bridging and enabling courses in mathematics and science subjects, as mentioned above. Alongside knowledge of mathematics and science, prospective students who have studied design and technology, and the small number of engineering science or engineering studies subjects, are likely to do well in engineering degrees. One ACED member whose faculty has been involved in the development of an Engineering Technology (ET) senior school subject has reported that over the past three years, 97% of the students who have competed the school ET subject have successfully completed their first year of university engineering with higher average GPAs than the whole first year cohort. School subjects in engineering are more likely to have credibility (for subsequent university study in engineering) if they are controlled by school science departments, and are taught by teachers with engineering qualifications and experience who have retrained in education.

Some universities have introduced specific aptitude tests in engineering as part of their recruitment strategies, reflecting that success in engineering needs much more than facility and understanding of mathematics and science.

The engineering faculties and the profession at large have not been idle in encouraging school students to consider engineering careers, and make appropriate school subject choices. Every engineering school would operate some outreach activities that supplement national programs, such as the *Science and Engineering Challenge* and *Re-Engineering Australia*. The *Robogals* program developed by the 2012 Young Australian of the Year is noteworthy, and timely, in its purpose to encourage more women into engineering.

Although commencing numbers in engineering are increasing, all this activity has not markedly increased the proportion of school leavers entering engineering: this is indicative of the complexity of the problem. Engineering is not widely perceived to be as desirable a profession as law or medicine, for example. There are several contributing factors, such as: most school students do not "know" any engineers or their very wide career opportunities; engineering work is seen to be subject to economic cycles; much of Australia's most challenging engineering work is done in remote areas. Engineering as a profession has not been marketed as successfully as accounting, for example.

ACED proposes that policy consideration is given to supporting growth in potential engineering enrolments in both university and VET sectors by action in the school education sector:

(i) The number of school students taking higher levels of mathematics and physical sciences in their secondary certificate must be increased, to underpin growth in all of the engineering qualifications offered by the higher education sector. Every effort must be taken to lift the persistently low participation rates of women (less than 15% in undergraduate programs) and of indigenous students.

(ii) The school curriculum in mathematics, science and other areas should be enhanced by demonstrating stronger connections between these areas and engineering. The opportunities offered by engineering study and careers should be more strongly promoted. Part of the solution here may lie in enhancing teacher education courses, or providing in-service training through the associations for science, mathematics and design & technology teachers.

Opportunities for graduates of disciplines other than engineering to formally qualify as engineers appear to have been limited. The introduction of articulated (3 + 2) degrees at The University of Melbourne and The University of Western Australia has opened up new opportunities. In fact, The

University of Sydney introduced a Master of Professional Practice in 2009 for precisely this purpose. Now accredited by Engineers Australia, small numbers of science graduates are taking advantage of this program to gain a degree that qualifies them for entry into professional engineering practice. The University of South Queensland has a similar program, with the advantage that much of the delivery is on-line. Further take-up of such programs may be assisted by policy intervention, as in recommendation (iii):

(iii) Mid-career entry to accredited engineering qualifications is relatively rare, although several universities are operating accredited masters degrees at professional engineer level for such purposes. Incentives and funding mechanisms to encourage expansion of numbers of qualified engineers for all levels deserve further consideration.

INDUSTRY COLLABORATION WITH ENGINEERING EDUCATION

Engineering qualifications are intended to prepare graduates for practice and employment. Engineering schools typically have industry advisory processes to assist them to define and deliver curriculum that ensures graduates are well prepared for practice. The program accreditation requirements set out by Engineers Australia focus on the delivering of a broad set of graduate outcomes that are the competencies required of an entry level graduate practitioner.

A specific requirement of the Engineers Australia accreditation processes for all occupational levels is for "exposure to professional practice". This may be done in a number of ways, but it is widely agreed that the most effective method is through a structured period of training in industry. Most universities specify a minimum of 12 weeks industry training for Bachelor of Engineering degrees, to be completed before graduation. A minority of universities build more extended structured periods of industry training into their programs. There are significant challenges in implementing good quality structured training, including: timing with respect to academic and industry schedules; structured training design, supervision and assessment; and finding and funding placements.

Studies (DEEWR, 2008, 9) have confirmed that students who have good industry training experiences are universally positive about it. In most universities, industry training is largely unfunded, as it lies outside the academic curriculum, and some students fail to complete the requirements before they have completed their academic work. They miss the opportunity to build on their industry experience in the latter stages of their degree.

There are also clear benefits to employers of having "engineers in training" on site as they can use the period of training for early recruitment, and can interact with the engineering school in other ways. Some of these might include guest lecturing (with the potential for all students to gain an understanding of a range of companies and their engineering challenges), industry-driven project work and case-study development. Involvement with industry early in engineering programs is likely to increase retention to graduation.

In the context of engineering skills shortages, having system-wide and effective industry input into engineering programs has proven value. Yet, as noted above, the activity is not adequately funded, or even available to all students. Policy development in the area would be highly desirable, as in recommendation (iv):

(iv) University engineering faculties and schools, and engineering industry should be encouraged to engage more closely to advise on curriculum development, provide case-study and project development, in-industry visits, structured training and scholarships,

joint appointments, etc., to enhance the quality of the engineering programs and the graduates' employability skills.

Given the wide range of expertise within the engineering faculties and associated research institutes and centres, the enrolment of Australian engineering graduates into postgraduate study in engineering is relatively low. Reasons for this may include employers' general satisfaction with BEng graduates and their abilities to learn and progress within the company, and a lack of knowledge of what the universities can offer. The university programs offered may not be relevant to industry needs. The apparent gaps between what is offered and what might be needed would appear to warrant further exploration, as in recommendation (v):

(v) Engineering industry groups should be encouraged to work together with the university sector to provide short-course or award programs in key advanced topics in high demand for practicing engineers.

REBALANCING ENGINEERING OCCUPATIONS AND CORRESPONDING QUALIFICATIONS

As discussed earlier, Australia is unusual in having much higher numbers of graduates from accredited engineering programs of 4 or 5 years duration that prepare graduates for entry to professional engineering occupations than from programs of 3years duration, designed for the engineering technologist qualification. Similarly, the numbers of graduates from AQF Level 6 awards in engineering is relatively low. This supply profile does not appear to match the occupational need in engineering industry.

To address engineering skills shortages more effectively in the long term, there may be a real opportunity to recruit a larger number of able students into 3-year BEngTech degrees and employ them effectively, at lower cost and greater overall satisfaction to all stakeholders than at present. Much more study of occupational needs would be necessary, however, to establish stronger positioning for this occupation and its educational pathway. The recent case of Chisholm Institute of TAFE introducing a BEngTech for the manufacturing industry is a positive outcome of collaboration that may be worth emulating elsewhere and for different industry sectors.

The current lack of data and uncertainty about the way to progress this matter leads to recommendation (vi):

(vi) Industry and the profession need to consider how the currently under-used occupational role and career of Engineering Technologist can be positively promoted within Australian industry, and thence to prospective students. In the long term, a more balanced workforce would reduce the costs of engineering services and education.

Recent studies and the Sydney pathways meeting referred to earlier discussed the evident downward trends in the numbers of students taking the Diplomas and Advanced Diplomas in engineering in the VET sector, and a shift to Associate Degrees provided by the universities. With the latter being mostly positioned by providers and viewed by students as pathways toward professional engineering qualifications, rather than for entry to practice as Engineering Associates, it would appear that Australian industry is likely to face very large future shortages of practitioners in this occupation. While further information is needed to determine the priorities for the development of Advanced

Diplomas, the evidence from the ANET occupational study on road and rail (ANET, 2011) underpins the need identified in recommendation (vii):

(vii) Industry groups, the profession, and educational providers and regulators need to examine how qualifications for Engineering Associates can be optimally formulated and delivered by university and VET providers in the locations and for areas of practice where there is high demand for these qualifications.

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