Economic contribution of engineering

FINAL Report for Engineering New Zealand

February 2020

Engineering New Zealand
PO Box 12 241
Wellington 6144

Attn: Helen Davidson, General Manager – Legal & Policy

13 February 2020

Value of engineering in New Zealand

Dear Helen

We are pleased to provide our final report regarding the economic contribution of engineering to New Zealand. This version of our report incorporates feedback in relation to our draft final report dated 24 January.

Please note that this report is provided in accordance with the terms of our engagement as set out in our contract dated 11 February 2019 and is subject to the restrictions set out in Appendix B.

Through you, we'd like to extend our thanks to Engineering New Zealand and the senior engineers who contributed to the workshop held as part of our work. The findings contained in this report would not have been possible without these contributions.

Yours sincerely,

Chris Gould

Director, Wellington

M. 021 462 374

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Executive Summary

Context

Engineering is integral to modern life. The buildings that form the distinctive skylines of our cities, the computerised networks of devices we use every day, the infrastructure upon which society depends (eg roads, water, electricity, hospitals and schools) – those and more are the products of engineering. The new challenges we face, including adapting to climate change, improving efficiency and making use of digital technologies, will all require and benefit from engineering.

Engineering is also about engineers. The people who train to become engineers make engineering happen. To maintain the contributions of engineering to modern life, we need to support new engineers to train and enter the profession. As EngineeringUK explains, 'In the face of technological advancements and a changing political and economic landscape, developing the pipeline to address the skills needs of the engineering sector remains a key challenge'.[1]

Developing support for engineers and engineering includes understanding the contributions they make. This report, commissioned from PwC by Engineering New Zealand, provides a first estimate of the value of engineering to the economy of New Zealand.

Economic impact

We estimate that engineering, viewed as a professional service, contributes $14.5 billion to $15.5 billion to the economy of New Zealand in 2019. Using these figures means that engineering accounts for in the order of five percent of the country's Gross Domestic Product (GDP).[2]

Engineering contributes around $15.0 billion per year to New Zealand, or about five percent of GDP

This estimate suggests that engineering, if it were considered as an industry, would be roughly the size of the whole primary sector (excluding mining).[3] It would be smaller than tourism (6.1 percent of GDP) but nearly three times as productive per employee ($213,000 of GDP per employee for engineering, versus $73,400 per employee for tourism). We also estimated the average remuneration for New Zealand engineers at $126,000.

These estimates are based on a combination of data from several sources and expert judgment, and are subject to a number of limitations described in this report. Limitations include the reliance on expert judgment, data limitations, reliance on certain definitions and a focus on GDP. As a result, the estimates should be considered initial approximations.

Workforce

Our work on estimating economic impact has focused attention on the number of engineers employed throughout the economy. There is uncertainty around the number and there are no official statistics. However, based on

1 EngineeringUK .Engineering UK 2018: synopsis and recommendations. London, https://www.engineeringuk.com/media/1576/7444_enguk18_synopsis_standalone_aw.pdf

2 Some care is needed with the figures. Official GDP statistics do not record engineers as a profession. The contribution to GDP has been calculated using estimates of the number of engineers and their typical remuneration. Unfortunately, there is no official data to corroborate the estimates.

3 Dalziel, P., Saunders, C., and Saunders, J. (2018). The New Zealand food and fibre sector: a situational analysis. Client report prepared for the Primary Sector Council. Lincoln University: Agribusiness and Economics Research Unit, Table 1-1, p. 2.

insights provided through a workshop involving senior engineers, the mid-point estimate of the number of engineers working in an engineering role is 73,650.[4]

This is a substantial number and it has some significant implications not least of which is the challenge of training and recruiting engineers for the future. For example, if it was assumed that engineering grows at the same rate as the economy overall and that the ratio of employment growth to economic growth remained constant, a (conservative) two percent rate of growth in the economy would mean a need to add almost 1500 engineers to the workforce each and every year. On top of this number, many more would be required to fill the gap created by existing engineers who retire, take up other occupations or leave the sector for other reasons.

Approach used

We held a workshop that included senior members of the engineering profession and facilitated several activities to obtain their understanding of the profession. We also investigated available data from Statistics New Zealand. By combining the two sources of information, we produced the estimates in this report.

The workshop activities included the following:

- Defining the boundaries of the analysis by describing ‘engineering’ and ‘engineers’
- Estimating the contribution of engineering in each of 86 industries, defined by Australian and New Zealand Standard Industrial Classification (ANZSIC) codes
- Estimating the extent of engineers by occupation, based on the Australian and New Zealand Standard Classification of Occupations (ANZSCO) classification.

These activities were the basis for the two different estimates of economic impact. There are several uncertainties associated with estimates, including the number of engineers employed in New Zealand, their remuneration and the relationship between their remuneration and the GDP impact.

4 The scope of our work has not required us to try and estimate the number of people who are trained as engineers but who work in non-engineering roles.

Introduction

Purpose of engagement

Engineering New Zealand engaged PwC to investigate the economic value of engineering in the country. The work focused on the direct economic or market value of engineering; as discussed below, flow-on impacts (sometimes referred to as multiplier effects), have not been assessed. The key aim was to provide a summary dollar-value estimate of the economic contribution of engineering to the New Zealand economy. A secondary aim was to provide a clear method to serve as a basis for future work.

Context

Contribution to Gross Domestic Product (GDP)
For the purposes of this work, we have estimated the economic contribution of engineering with reference to GDP. GDP is a measure of the (market-based) value added in an economy over a defined period of time (typically quarterly and annually). Currently (2019), New Zealand's annual GDP amounts to slightly over $300 billion. We have sought to estimate the share of this number that can be attributed to engineering.

The contribution to GDP is an estimate – not a definitive number
Assessing the economic contribution of engineering is not straightforward for the reason that there are no official statistics that provide this information (because of the way in which economic data is categorised here and internationally). Although explained in more detail in the next section of the report, our estimate depends on how the scope of the engineering profession is defined. Different people will have different interpretations in this regard so we have endeavoured to be as explicit as possible in the definition we have used (Appendix A refers). The estimate also depends quite critically on judgements regarding the number of people who are employed in engineering roles (and, again, there are no official statistics on this).

Limitations
There are some limitations with the approach taken that need to be noted. Two limitations in particular should be noted.

- GDP is a backward-looking measure of value add. It is calculated with reference to economic activity that has occurred. One of the characteristics of engineering is that the work of engineers is often directed to creating assets that have long life-spans and that provide a stream of benefits that can exist over many years or decades. Many forms of infrastructure are a good example of such assets. Measures of GDP do not necessarily capture the longer term benefits that flow from the investment made in creating the asset.

- Economic activity in one area often will have flow-on implications for activity in other areas (this is often referred to as a multiplier effect). There are good grounds for thinking that this is particularly true in respect of engineering. This is because engineering is widely seen as playing an important role in fostering dynamism in an economy via its role in innovation. The engineering sector has a long tradition of embracing new technology and adopting existing technology to address new problems. Innovation drives productivity growth, which allows economies to produce more output for the inputs they use. The impact of research on productivity and economic growth has been demonstrated for New Zealand using long-term economic data.[5] Tracking these flow on impacts is, however, challenging and is well beyond the scope of this project.

The key implication of these two main limitations is that the estimate of engineering's economic contribution contained in this report is likely to be conservative. Addressing the limitations noted above would, almost certainly, lead to greater numbers than those included in this report.

There is one further limitation to note and this stems from the terms of reference for this work. Our work has focused on the economic contribution of engineering. There is an unknown number of people who have trained as engineers but who are not working in engineering roles. Our work has not sought, or been required, to estimate the number of these people let alone estimate the economic contribution of their work.

[5] Hall, J. & Scobie, G.M. (2006). The role of R&D in productivity growth: The case of agriculture in New Zealand: 1927 to 2001. New Zealand Treasury Working Paper 06/01, Wellington.

International research
EngineeringUK has been investigating the economic impact of engineering for several years. Their approach is a good example of research that has sought to address aspects of the limitations noted above. In 2018, they reported:[6]

> *Our findings show that engineering is a crucial sector for raising the UK's productivity levels. Research by the Centre for Economics and Business Research (Cebr) on EngineeringUK's behalf found that the engineering sector had a strong multiplier effect on the economy, generating a further £1.45 Gross Value Added (GVA) for every £1 GVA created directly in the engineering industries. What's more, every additional person employed through engineering activity was projected to create a further 1.74 jobs down the supply chain. Overall, they estimated that the engineering sector generated 25 percent of the UK's total GDP in 2015 (£420.5 billion).*

If the multiplier effect noted above was put to one side, then the estimated contribution of engineering to the UK's GDP would be more in the order of 10 percent (rather than 25 percent as noted above). In short, the multiplier effect can be substantial.

Context is important, however, when considering the multiplier effect. The work undertaken by the Cebr[7] noted that nearly half of the economic impact of engineering flows through the UK manufacturing sector. This proportion is important to understand because of the relatively smaller manufacturing sector in New Zealand.

An interesting and related point to note from the UK work is that the method used for the analysis shows that the sectors labelled 'engineering sectors' span the whole economy. In other words, engineering as a profession has wide influence and this is borne out in the industry and occupation data included in Appendix A of this report.

Research in the US has also pointed to the importance of engineering. A report from the Brookings Institution,[8] found that 11 percent of all jobs relied on a high level of engineering knowledge.

Another place where the economic impact of engineering has been studied is Ireland. A report from 2009 for Engineers Ireland investigated the occupations that were filled by qualified engineers. They estimated that there were nearly 70,000 engineers and engineering technicians in Ireland in 2008, representing 2.3 percent of the Irish workforce. They produced 3.4 percent of the GDP of the Republic of Ireland and 6.7 percent of the GDP of Northern Ireland.

Communicating the impacts
It is important for organisations and professions to explain their contributions to wider audiences, including policy-makers, students and the general public. One way to do that is to estimate their economic impact and communicate about it in an accessible way. The dollar value of their contribution to GDP is a simple way to explain their impact.

One example of similar work is research that PwC conducted for the design industry. Design, like engineering, can be hard to define precisely. Those engaged in it know what they do, but drawing a boundary around it for statistical purposes can be challenging. PwC worked with a consortium of people and organisations involved in design, DesignCo, to describe their work and estimate an economic impact. The research, launched by the Minister of Finance in 2017, found that design contributed $10.1 billion to the New Zealand economy.[9] This work provides an example of summarising a diverse body of work in a single estimate of economic impact, and communicating with policy-makers about the impact.

Another example is the work that Plant and Food Research has conducted and commissioned over several years to understand the economic contribution of their research and innovations.[10] The evaluations are then used in the annual reports from the Crown Research Institute. The reports describe the science that Plant and Food does, and then summarise the economic value based on the evaluations. The information is intended for a diverse audience, but in particular communicates the important of science to the shareholding Ministers and other people involved in policy.

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6 EngineeringUK .Engineering UK 2018: synopsis and recommendations. London, https://www.engineeringuk.com/media/1576/7444_enguk18_synopsis_standalone_aw.pdf
7 Cebr (Centre for Economics and Business Research). (2015). The contribution of engineering to the UK economy – the multiplier impacts: A report for EngineeringUK. London.
8 Rothwell, J. (2013). The hidden STEM economy. Washington, D.C.: Brookings Institution Metropolitan Policy Programme, June.
9 PwC. (2017). The value of design to New Zealand. Auckland, July.
10 Greer, G. & Kaye-Blake, B. (2017). The impacts of research in an era of more stringent performance evaluation. New Zealand Agricultural and Resource Economics Society conference, Rotorua, October.

This report is an initiative by Engineering New Zealand to do something similar. The aim is to have a robust estimate of economic value that can be shared widely to demonstrate the value of engineering.

What this report does

Measuring GDP contribution

The New Zealand economy is estimated at about $300 billion in annual GDP in 2019. As at June 2019, there were approximately 2.68 million people employed in New Zealand.[11] The economy is usually presented as a collection of industries. Each industry has a standard label, provided by the Australian and New Zealand Standard Industrial Classification (ANZSIC). A figure showing the economy and its industries (by percentage) is provided below.

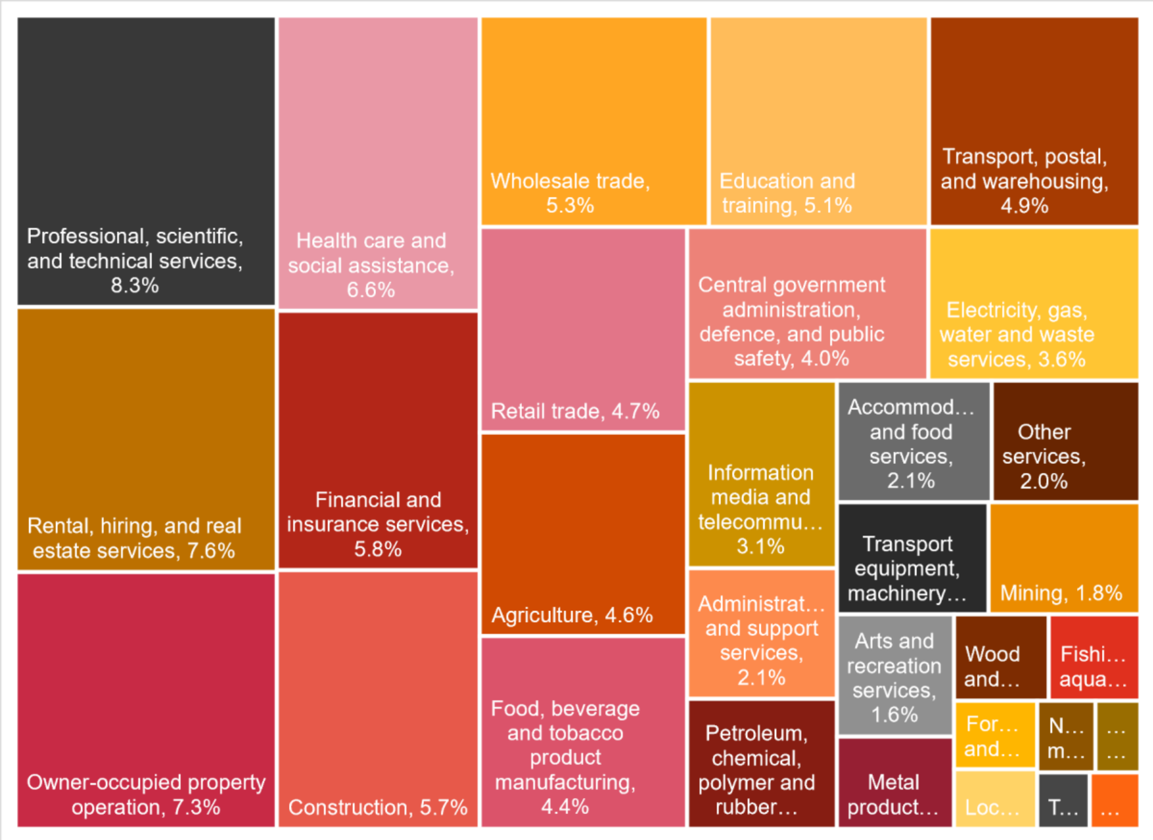

Figure 1 New Zealand economy by ANZSIC industry, 2013

There are two things to notice about this figure. First, the industries are organised around the goods and services produced, such as food, health care or electricity. Each one includes people with different skills, jobs and pay levels. To understand how engineering contributes to the economy, we cannot just select the 'engineering' industry. Instead, we must look inside each industry. Second, the economy is diverse. Economies like that of New Zealand produce mainly services – wholesale trade, retail trade, transport, professional services and the like. The primary sector – agriculture, mining and so on – is generally a small part of the economy. Manufacturing tends to fall somewhere in between those two. As a result of the diversity, any single skill or profession is a small part of the whole.

Many people want to know their economic contribution. Industries want to understand their contribution to the country and want to demonstrate their importance to the public and policy-makers. For example, the Ministry for Primary Industries routinely reports on the GDP contribution of agriculture in its annual State of Primary Industries report. Scientists and research organisations want to describe their contribution to growth and innovation, in order to show that they are having an impact and to support future funding. There are several examples of this type of work, such as work by ACIL Allen to estimate the contribution of CSIRO in Australia, and research in New Zealand

[11] Source: Statistics New Zealand Household Labour Force Survey June 2019

to estimate the economic contribution of the Apple Futures programme to the pipfruit industry. Individual professions also investigate their economic contributions in order to raise their profile among the public, students and government. PwC estimated the value of the design industry to New Zealand, and the Royal Academy of Engineering estimated the value of engineering in the UK.

There are three key issues that arise with these estimates. One adding-up problem is that each individual report or assessment tends to use an expansive definition of 'impacts', casting the net widely for direct and indirect and wider economic impacts. If all the impacts were added up, they would be larger than the actual economy. A second adding-up problem concerns the value of productivity improvements. Individual technologies or innovations are assessed as highly productive, producing large benefits over time. However, the actual economy tends to grow more slowly than the sum of all these productivity gains. A third problem is one of attribution and allocation. It is difficult to attribute specific economic contributions precisely to different causes, or to allocate responsibility among several contributors. This is often an issue when assessing the value of science. An innovation may depend absolutely on a piece of scientific progress or insight. However, achieving economic impacts also requires patent lawyers, accountants, marketers, manufacturers, distributors, and so on. Allocating the economic value among the contributors is a matter of judgment.

Summary of the method

One approach to dealing with the uncertainty around estimating economic impacts is to use multiple methods and triangulate among them. For this research, we have used two different methods. They are discussed below. The aim was to produce two estimates in different ways and then compare the results. Both the similarities and differences would provide some guidance about the economic contribution of engineering.

There are generally two approaches for measuring economic value. One is top-down. It starts with economic data and models and uses them to estimate contributions as a percentage of the whole. One of the key benefits of this approach is that it ensures consistency of the data, which are all taken from the same source. The analysis of the economic contribution of engineering sectors in the UK by Cebr[12] is an example of this approach. A second approach is bottom-up. This approach starts with an innovation or business and describes its economic impacts. An example in the New Zealand context is the valuation of innovation in the pipfruit industry.[13] This case study approach provides a better description of all the pathways for economic impacts, but is more likely to produce estimates that are inconsistent with the sum of all economic activities.

The work described here uses a hybrid approach, one that has been used in other PwC work.[14] The approach starts with data about the whole economy or a whole industry, as a way of anchoring the analysis to market and economic data. It then uses expert judgment gathered through facilitated workshops to describe economic impacts in more detail. The details can be focused specific innovations, companies or professions. The hybrid approach captures some of the richness of case studies, but is also somewhat bounded by economic data like the top-down approach.

A first attempt at estimating the economic contribution of engineering

This report presents the results of a short project to provide Engineering New Zealand with the first estimate of the economic contribution of engineering to New Zealand's economy. The aim was to produce an estimate, but also to spark a discussion of economic impacts, how they fit into the economy and how they might be observed and measured. In the future, more detailed research could be pursued. For example, a more data-intensive approach could investigate different sources of data and develop a tailored economic model. Another approach would focus on more engagement with engineers and businesses, to investigate how engineering influences the value they produce. We hope that future work is able to build on the start we have made here.

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12 Cebr (Centre for Economics and Business Research). (2015). The contribution of engineering to the UK economy – the multiplier impacts: A report for EngineeringUK. London.

13 Williams, T., Park, N.M., Kaye-Blake, W., and Turner, J.A. (2015). Apple Futures – a quantitative and qualitative evaluation of impact created for New Zealand's pipfruit sector. INRA Impact of Agricultural Research conference, Paris, November.
Kaye-Blake, W. & Zuccollo, J. (2012). The economic impact of the Apple Futures programme. New Zealand Association of Economists conference, June.

14 Greer, G. & Kaye-Blake, B. (2017). The impacts of research in an era of more stringent performance evaluation. New Zealand Agricultural and Resource Economics Society conference, Rotorua, October.

Economic contribution of engineering

Key findings

Using the process described below, we estimate that engineering as a professional service contributes $14.5 billion to $15.5 billion to the economy of New Zealand in 2019. Using an average of those figures, we estimate the annual economic contribution of engineering to be $15.0 billion. The New Zealand GDP is estimated to be $300 billion in 2019, so engineering contributes about five percent of the country's GDP.

For reference, this estimate can be compared to the GDP contribution of specific industries. The total share of the primary sector (excluding mining) has been estimated at five percent of GDP.[15] The total GDP contribution of dairy farming (Dairy Cattle Farming) and dairy processing (Dairy Product Manufacturing) has been estimated at 2.9 percent of GDP.[16] Tourism is an example of an industry whose size is estimated with a 'satellite account', which reconfigures data from several industries, such as accommodation, food retailers, etc. Its contribution in 2018 was estimated at 6.1 percent of GDP.[17]

We were also able to generate estimates of the number of people employed in engineering or as engineers. Our method produced estimates of 59,400 to 87,900 engineers currently employed in New Zealand, for an average of 73,700 engineers which is about three percent of the workforce (of circa 2.7 million). Combined with the GDP estimate, this figure suggests that engineering positions produce on average $213,000 of GDP per employee.

For comparison, the average across all people employed in New Zealand is about $112,000 in GDP per person. The tourism sector employs more people, with direct employment in the sector estimated at 216,000 people.[18] However, the GDP contribution per employee is only about $73,400. Engineering by comparison is a relatively high-value and high-productivity activity.

Based on mid-point estimates:

Engineering contributes around $15.0 billion annually to New Zealand, or about five percent of the country's economy.

Engineers working in engineering roles total around 73,700 or about three percent of the workforce

Data

To estimate the economic contribution of engineering, we started with official statistics concerning the size of different industries in New Zealand and the number of people employed in different occupations. There are two reasons to use these figures. First, they allow the research to move from somewhat qualitative information about the extent of engineering to specific estimates of GDP contributions and employment. Second, they ground the analysis in official estimates of the overall size of the economy and employment. This grounding is important to help avoid making specious claims about economic impact. One danger in this type of economic analysis is that the claims from all the interest groups, when added up, imply an economy much larger than the actual one. By grounding the analysis in official figures, we hope to avoid this type of claim inflation.

Data came from a few sources. The main source was the PwC Regional Industry Dataset (RID), a proprietary dataset that estimates GDP and FTEs by 3-digit ANZSIC code for all Territorial Authorities and Districts in the

15 Dalziel, P., Saunders, C., and Saunders, J. (2018). The New Zealand food and fibre sector: a situational analysis. Client report prepared for the Primary Sector Council. Lincoln University: Agribusiness and Economics Research Unit, Table 1-1, p. 2.

16 Ibid, Table 1-1 and Table 1-2, pp. 2 and 3.

17 Statistics New Zealand. (2018). Tourism satellite account: 2018, Table 14.

18 Ibid, Table 7.

country. The underlying data for the RID is sourced from Statistics New Zealand and MBIE. In addition, further data was sourced directly from Stats New Zealand. The details of the data are as follows:

- PwC RID – This dataset gave us the GDP contribution and the number of FTEs for each of 86 industries in New Zealand. The groupings were the 2-digit ANZSIC codes for industries (eg A01 Agriculture, A02Aquaculture, etc). The most recent RID figures are from 2016.
- National Accounts input-output tables, year ended March 2013 – Periodically, Statistics New Zealand produces tables that describe how industrial sectors in New Zealand interact with each other. They show, for example, the value of inputs from the consulting, marketing, and petroleum industries to the horticulture sector. The most recent tables are from 2013 and are commonly used for this kind of analysis.
- Occupation counts – We used 2018 Census data for the number of people employed in each occupation. Occupations are classified according to ANZSCO classification system, and we focused on occupations at the 6-digit level, such as 133211 Engineering Manager.
- National accounts – Statistics New Zealand is responsible for producing estimates of the country's GDP. We have used the Gross Domestic Product – expenditure measure in nominal dollars in order to adjust our sector GDP figures from 2016 to 2019.
- National employment – The Household Labour Force Survey (HLFS) conducted by Statistics New Zealand produces estimates of the employment. We have used the seasonally adjusted estimate of the number of people employed to adjust both the 2018 Census estimates of employment by occupation and the 2016 RID of FTEs by industry.

The core data for the analysis was thus based on official counts and estimates relevant to the New Zealand economy, specifically industry and occupation estimates around GDP and employment.

No 'satellite account' for engineering
Importantly, engineering does not have a 'satellite account'. A satellite account re-calculates or allocates national account data, such as estimates of GDP contribution, in order to estimate the impact of an activity or industry not included in the internationally recognised method for producing official statistics. The main example in New Zealand is the Tourism Satellite Account. Statistics New Zealand has developed a method for allocating GDP in standard sectors, such as accommodation and retail sales, into an estimate of the value of tourism to the New Zealand economy. A recent report from the New Zealand Institute of Economic Research (NZIER) recommended that a similar satellite account be constructed for the forestry sector, to account for the value-added processing activities and produce a complete picture of the value of the sector.

Without such a satellite account for engineering, we have had to produce our own estimates.

Workshop

The key challenge of the project was to understand where and how engineering contributes to the New Zealand economy. Engineering is a wide field with many specialities, and engineers are found in many roles and organisations. Because their activities and contributions are not specifically tagged in any dataset, we needed a way to identify them.

PwC worked with Engineering New Zealand to plan and facilitate a workshop of senior engineers from across the field. The workshop was held at the Engineering New Zealand office in Wellington. PwC facilitated a set of activities designed to prompt the participants to share their knowledge of the profession. The workshop included several activities. The two key activities for estimating the economic contribution of engineering are described below.

Occupations – describing the work of engineers
The aim was to have participants identify all the different jobs that engineers do and estimate remuneration figures for those jobs. Participants started with a list of 45 occupations that included 'engineer' or close variant in the title. Working in groups, they described the work involved for that occupation, the proportion of those people who are engineers and the average remuneration for the occupation.

This exercise had two key strengths. First, it did not work from a consensus view of what an engineer is, and then assign people to that definition. Instead, it allowed participants to decide for each occupation the proportion that should be considered engineers. This approach allowed participants to use their implicit understanding of 'an engineer' to categorise employees without needing to make the definition explicit. Second, the approach created a direct estimate of a portion of the GDP contribution. Returns to labour – including wages and salaries – are one of the main components of GDP. By estimating remuneration, which is a familiar concept, participants were also estimating a key component of the engineering contribution to GDP.

The output from the activity was a list of occupations, the proportion in each occupation who are engineers and the average remuneration per occupation. For some occupation, remuneration was expressed as two or three categories, such as 'Graduate 50k, Senior 120k, Principal 200k'.

Industries – describing the contributions of engineers
The aim of the second main activity was to work through the economy industry-by-industry to describe the contributions of engineers. Participants were provided with A3 worksheets, each of which included several ANZSIC industries. For example, one worksheet focused on ANZSIC code A, which has five 2-digit sectors: A01 Agriculture, A02 Aquaculture, A03 Forestry and Logging, A04 Fishing, Hunting and Trapping and A05 Agriculture, Forestry and Fishing Support Services. ANZSIC code C has 15 2-digit sectors, which were spread across 3 worksheets. Each worksheet had areas for describing how engineering contributed to those specific sectors, and boxes for estimating the number of engineers employed in the sectors. Participants were provided with total national FTE counts by sector from the RID to help them estimate the number of engineers in the sectors. Participants worked in groups to complete the worksheets, and then all the worksheets were laid out for people to inspect and discuss.

The key output from this activity was an estimate of the number of engineers working in each industry.

Estimating the economic contribution

The two workshop exercises assessed economic activities from two perspectives: industry-by-industry and occupation-by-occupation. Conceptually, it is possible to think of a table that combines both perspectives and indicates the number of people in each occupation employed in every industry. Unfortunately, that data is not available for New Zealand. Instead, the two perspectives allowed us to produce two estimates of the economic contribution of engineering.

By occupation
From the 2018 Census, we know how many people are employed in each occupation. From the HLFS, we know the aggregate growth in employment from 2018 to 2019, which allows us to estimate the current (2019) employment by occupation. From the workshop, we have the proportion of each occupation that are engineers and their average remuneration. Finally, the National Account input-output tables provide an estimate of the ratio of employee compensation to total value add (that is, total GDP). Together, these data allow us to estimate the economic contribution of engineering by occupation and for the whole economy. An example of the calculation is provided below.

Calculation for Engineering Manager (ANZSCO 133211):

- Greater than or equal to 90 percent of the occupation are engineers (from workshop)
- Average remuneration is $150,000 (from workshop)[19]
- Total people in the occupation is 2,130 (from Census)
- Employment has grown 1.7 percent from 2018 to 2019 (from HLFS)
- Employee compensation is 48.4 percent of GDP (from National account input output tables)[20]
- GDP contribution is 0.90 * $150,000 * 2,130 * (1 + 0.017) * (1 / 0.484) = $604 million.

The same calculation was made for the other occupations. The total estimated GDP contribution using this method was $15.5 billion. The total number of engineers was estimated at 59,400.[21]

[19] To be consistent with the way GDP is calculated (using an incomes approach) remuneration should, in addition to wages/salaries, also include any bonuses paid, fringe benefits (in cash or in kind) as well as KiwiSaver contributions and ACC employee premiums. We note from the 2019 Engineering New Zealand Remuneration Survey that the median base salary for engineers is just under $91,000. The same survey reports that nearly a fifth of those surveyed benefitted from a work-provided car and car park and 29% received health insurance as part of their remuneration. It is important to note also that the survey records median base salary; not the mean which generally can be expected to be higher than the median.

[20] We note this figure might slightly overstate the contribution to GDP. Based on 2018 data from Statistics New Zealand, compensation of employees for the professional, scientific and technical services group was about 53 percent.

[21] This estimate is lower than the 83,552 people who, in the 2018 Census, indicated that they worked in one of the 45 occupations relating to engineering. As discussed above, however, the view of the workshop was that not all of the occupations comprised solely engineers. For example, of the almost 1000 people who indicated in the census they were a civil engineering technician, the view of the workshop was that between five and ten percent of these people could be considered to be engineers.

Secondarily, we were able to estimate the average remuneration of New Zealand engineers. The estimate was based on the sum of total remuneration across all occupations divided by the total number of engineers. The result was $126,000 in annual remuneration.

This calculation works as an estimate of the value of engineering because it starts from the senior engineers' understanding of the work that engineers do and how much they are paid for the work. By focusing on each occupation in isolation, the workshop participants could knowledgably consider whether anyone in that occupational category should be considered an engineer. Estimates ranged from 100 percent (eg Aeronautical Engineer) to none (eg Civil Engineering Draftsperson). It also worked from a base of salaries and wages. Employee remuneration or compensation would be fairly widely known by senior people in the field, especially with employers and senior managers taking part in the workshop. By working from employee compensation to total GDP contribution, the process uses a standard ratio from official data and takes into account the returns to capital that can be attributed to engineering. As a concrete example of the returns to capital, specialised equipment used by mining engineers can be considered part of engineering's contribution to GDP. This calculation builds on the expert knowledge of workshop participants to produce a holistic estimate of the economic value of engineering.

There are limitations to this approach. One limitation is the validity of the data: the estimate depends on the validity of the RID, Census, HLFS and National Account data. A second limitation is the reliance on the workshop approach: the workshop figures were produced by a group of people on a specific day and subject to their limitations and biases. A third limitation was the interpretation of the workshop outputs for use in the economic modelling: some of the information was ambiguous and needed to be interpreted.

The final limitation concerns use of the ratio of employee compensation (ie remuneration) to GDP ratio (which is a key element in the calculation). This ratio acknowledges that engineering as a field contributes more to the economy than just the amount that engineers as professionals are paid. The additional contributions arise from the use of engineering-specific capital and other resources, such as intellectual property and includes profits (ie return on capital).The ratio of employee compensation to GDP differs between industries reflecting, for example, different levels of capital intensity. Unfortunately, there is no official data to help determine the ratio in the context of engineering. Accordingly, we have resorted to using an economy-wide figure. Overall, the impact of this approach is unknown and could result in either an upward or downward bias in the results.

By industry
The industry calculation was shorter. The RID provided the 2016 GDP by industry as well as the FTE count by industry. The number of engineers was estimated by workshop participants, and those estimates were used to calculate the percentage of FTEs that were engineers. This proportion was then taken as an estimate of the proportion of GDP in each industry that can be attributed to engineering. GDP by industry was adjusted to the 2019 level using the GDP series from Statistics New Zealand. The data were combined to produce an estimate of the contribution of engineering to each industry and to the whole economy. An example is provided below.

Calculation for A01 Agriculture:

- 2016 GDP is $9,116 million (from the RID)
- 2016 FTEs are 152,381 (from the RID)
- GDP growth from 2016 to 2019 was 17 percent (from the GDP series)
- Estimated number of engineers is 300 (from workshop)
- GDP contribution is $9,116 * (300 / 152,381) * (1 + 0.17) = $20.9 million.

This calculation was made for the 86 ANZSIC sectors. The total estimated GDP contribution according to this calculation was $14.5 billion. The estimated number of engineers was 87,900.

This calculation works by apportioning the value of each industry between engineering and everything else. The basis is the employment split between engineers and all other fields. The GDP of each industry is then attributed to engineering in the same proportion as the employment split. The approach does not consider whether engineers are contributing more or less value than the average employee in each industry, nor does it investigate the relative returns to labour and capital and how to assign those returns to engineering. Instead, it treats engineering as integral to the industry and proportionate in its contributions.

There are limitations to the industry approach as well. Data validity is again a limitation, as is the reliance on the workshop approach. A third limitation is the implied proportionality of engineers versus other categories of employees. By basing the calculation on the ratio of engineers to total employment in an industry, the implication is that engineers are, on average, as productive as any other employee in the industry. Overall, the impact of these limitations is, again, unknown and could result in either an upward or downward bias in the results.

Summary estimate

The summary estimate is an average taken from the two methods described above. The results are provided in the table below, along with the corresponding figures from the national economy. Taking the average of the two methods implies that the estimated annual contribution of engineering to GDP is around $15.0 billion in 2019, or about five percent of the national economy. The average estimated number of engineers is 73,650 people or about three percent of the workforce. Importantly, these figures suggest that engineers produce on average $213,000 in GDP per employee. This figure is nearly twice the average GDP per employee for the economy, indicating that engineers are highly productive.

Table 1 Estimated economic contribution of engineering in New Zealand, 2019

Figure estimated	Engineering Estimate by industry	Engineering Estimate by occupation	Engineering Average estimate	Total economy
GDP contribution ($b)	14.5	15.5	15.0	300
Total employed	87,900	59,400	73,650	2,680,000
GDP per employed person ($)	165,000	261,000	213,000	112,000

Some care is needed with the estimates. The estimated contribution to GDP depends heavily on estimates of the number of engineers and their remuneration. Unfortunately, there is no official data on either of these metrics.

By implication, the estimated contribution to GDP could fall within a range wider than the $14.5 billion to $15.5 billion indicated above. For example, if the true number of engineers was, say, 87,900, then the occupation-based method described above would imply a contribution to GDP of about $23 billion (about 7.6 percent of GDP). Equally, if the true number of engineers is only 59,400, the industry approach would imply a contribution to GDP of about $9.8 billion (or about 3.3 percent of GDP).

Leaving to one side the uncertainty around the numbers (and the limitations noted earlier), it is clear that engineering makes a significant contribution to the economy. One implication of this is that as the economy grows, the number of engineers will need to increase. For example, if it was assumed that engineering grows at the same rate as the economy overall and that the ratio of employment growth to economic growth remained constant, a (conservative) two percent rate of growth in the economy would mean a need to add almost 1500 engineers to the workforce each and every year. On top of this number, many more would be required to fill the gap created by existing engineers who retire, take up other occupations or leave the sector for other reasons.

Further research

The aim of this short project has been to produce an estimate of the economic contribution of engineering, but also to spark a discussion of economic impacts, how they fit into the economy and how they might be observed and measured. In the future, more detailed research could be pursued. For example, a more data-intensive approach could investigate different sources of data and develop a tailored economic model. Another approach would focus on more engagement with engineers and businesses, to investigate how engineering influences the value they produce. We hope that future work is able to build on the start we have made here.

How engineering contributes

What is engineering?

A first step in measuring the impact of engineering is to define engineering. Workshop attendees provided a large amount of information on their perceptions of engineers. Details of their contributions can be found in Table 2 in Appendix A.

They are summarised in a wordcloud in Figure 2.[22]

Figure 2 ‘Engineering is…’ wordcloud

The workshop discussion canvassed ideas similar to a report for the UK Royal Academy of Engineering. A 2016 report[23] noted:

> *Engineering covers many different types of activity. Engineers make things, make things work and make things work better. They also use their creativity to design solutions to the world’s problems and help build the future. Engineering has previously been defined by the Royal Academy of Engineering as the ‘creative application of scientific principles’, principles that are put in practice to invent, design, build, maintain and improve structures, machines, devices, systems, materials and processes.*

The problem of defining engineering is solved in different ways by researchers:

- Cebr in its UK work has defined engineer as ‘engineer sectors’.[24] It identified and listed a set of industry sectors and subsectors that are considered ‘engineering sectors’, and then identified the economic value of them. The list is extensive, and the sectors amount to about one-quarter of the UK economy.

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22 Wordcloud produced with https://www.wordclouds.com/. Words with frequency of one were not included, and the tool omitted 30 additional words to generate the figure.

23 Cebr. (2016). Engineering and economic growth: a global view. Report for the Royal Academy of Engineering, London, September.

24 Cebr (2015) and (2016).

- An assessment of the economic importance of engineers for the island of Ireland focused on their occupations, and defined engineers as a 'member of the engineering profession…who has successfully completed a level 6 or above engineering programme.'[25]

Extensive economic impacts

Prior work and the results from the workshop highlight the extensive economic impacts of engineering. The workshop used the occupation labels from the ANZSCO classification; the full list is available in the appendix in Table 4. Similarly, the prior research in Ireland used the following occupation list:

- civil/mining engineers
- mechanical engineers
- electrical engineers
- electronic engineers
- software engineers
- chemical engineers
- design and development engineers
- production engineers
- planning and quality control engineers
- other engineers and technologists not elsewhere classified
- engineering technicians
- building and civil engineering technicians.

These lists show the extensive impacts. Engineers are involved in building and maintaining roads and other horizontal infrastructure; creating and maintaining the machinery used in manufacturing; developing the electronics for new products; developing chemicals for industrial applications; and much more. These activities have impacts across the three main economic divisions: primary (agriculture, mining, etc), secondary (manufacturing) and tertiary (services, including professional services).

In the workshop, we asked participants to describe the impacts in each of the sectors. A sample of some of the description is:

- Agricultural Engineer – Design, construction oversight + maintenance. Farm systems + infrastructure, irrigation
- Environmental Engineer – Assess, design + build infrastructure + environmental systems related to impact on the environment
- Engineering Technologist – Applied engineering across various fields (civil, structural, electrical, mechanical, etc.) limited design + oversight
- Biomedical Engineer – Design, build + maintain mechanical equipment + prosthetics + diagnostic equipment + software
- Aeronautical Engineer – Design, assurance, certification, construction oversight + maintenance oversight of aircraft + related systems.

The descriptions across the many occupations described illustrate the wide range of skills and activities involved, and therefore the wide range of economic impacts.

[25] DKM Economic Consultants. (2009). Economic importance of engineers. Report for Engineers Ireland. https://www.ey.com/Publication/vwLUAssets/ey-economic-importance-of-engineers/$FILE/ey-economic-importance-of-engineers.pdf

The impact of building assets

One important idea from the workshop was that engineering builds long-lived assets. As a result, the contributions of engineering continue over time as the assets continue to be used.

Economic analysis recognises the difference between stocks and flows, or wealth and income. Some of the discussion around assets focused on the stock of assets created. However, the approach used in this research focused on income measures – the work done in the current period by engineering. This approach was consistent with other economic research, such as the PwC value of design report, which focused on the contribution to current production, measured by change in GDP.

The key point is that the value of assets can be measured using a wealth approach or an income approach, but the two should not be added together because of the risk of double-counting.

Appendix A Workshop data

Table 2 'Engineering is...' – responses from workshop participants

Creative. Transformative. Uses resources for better society/world.
Applying an evidence-based approach to a problem, then designing, implementing and maintaining a solution.
Creative and robust application of known and evolving scientific knowledge to the world's challenges. Resources - efficiency. Betterment. Design.
Using science and technology to create a better world. "Applied Science". Designing, creating and maintaining new products, systems, …etc. services.
Bringing knowledge and analysis to innovation. Design for assured performance, value, and safety.
Application of science (and arts!) to provide (or maintain) a capability/service/action/product.
Problem solving; solutions finding; innovation; management of initiatives; championing safety; risk management; engaging with community; improving humanity; stewardship of the environment.
The implementation of everything that society needs to function, including buildings, roads, infrastructure and manufacture of products required to live, including foods and consumer goods. Applying science and technology to create improving humanity. Is it the skills you've learnt or the work you're performing.
Design, constructs and maintains; Solve problems; Traditional education (tertiary); Sub-disciplines ie Civil, structural, mechanical, geotech, ICT, biomedical. NOT a person who operates machinery. Balance for a common good (efficiency).
Engineering is: problem solving; creative use - achieve goals; making some things work before they start; practical application of sci, tech and arts; balancing risks; ethics - good & right; improving lives; analysis to innovation; design, creation implementation; enabler.
Infrastructure; safety; environment; quality of life; sustainability; economics; through + problem solving - balancing risks for common good; maths, science, arts; lifecycle.
Application of science, technology and innovation in the real world to solve problems.
Noble: Harnessing the power of nature for benefit of humanity and protecting humanity by resisting power of nature.
Practically: The work carried out by those with engineering knowledge & skills - distinguished from science as "know-how" not "know-what" and by purposeful synthesis of practical solutions to meet needs, and avoiding irreversible degradation of resources and the environment.
The process of creatively applying science and technology to provide effective solutions to improve the lives of people.
The art or science of making practical application of science and mathematics in the design and build engines, bridges, buildings, vehicles efficient. To improve the lives of people.
Value add problem solving; applied problem solving; structured + systems thinking - 1st principles; learnings from research; solution orientated; R&D - more D; Steam - arts; commercialisation - future state; creative + innovative; creation of intellectual property; delivering economic value.
The application of science & creativity to create & deliver outcomes that benefit society, and the world at large. Infrastructure for life support, trade & heart of soul of communities.

Solving problems; application of scientific knowledge to design, construction, maintenance. Qualification - tertiary? Operations - ongoing delivery.
Problem solving; designing/creating/innovating; delivering of real-world solutions mostly in built/materials/systems environment thought; Steam; systems thinking orientation.
Invention, design, construction and operation of objects/products of use to people/society.
Making sure things will work before you start. From conception to delivery + continuously improving (problem solving) solutions. Opportunity - apple "no problem required"…here is a solution.
Creative use of resources to achieve a goal; innovative use of resources and I? to achieve a goal; imagination; creating opportunities; opportunity creation; physical.

Table 3 Contributions of engineers and engineering by ANZSIC industry

ANZSIC industry	Contribution of engineers/engineering
A Agriculture, forestry and fishing	Manufacturing + process engineering. Engineers otherwise engaged in farming + using skills there. environmental assessments + compliance, civil engineering + road building, machine repair
B Mining	Geotechnical, civil, machine design + maintenance, chemical engineering, environmental impacts + management
C Manufacturing	Product design, machine management design Manufacturing Engineering, Software Engineering, Optimisation Process engineers; Sales engineers; Engineering technicians; Health and safety systems; Machine and process design; Manufacturing + process setting/validation Design, production, development and implementation Maintenance of manufacturing equipment
D Electricity, gas, water and waste services	System planning + design. Maintenance. Management. Sales. Asset management
E Construction	Structural engineers, civil engineers, metallurgical, (welding), environmental + regulatory compliance
F Wholesale trade	Warehousing and stock control, forklifts. Automated warehousing Input into ITC support or design. Safety - Health & Safety, fire/compliance. Freight Logistics included. Software management/development. Fleet management/procurement of logistics Refrigerated technology. Support for maintenance + operation + compliance, health + safety
G Retail trade	Once built and designed, minimal input other than compliance and ongoing operation Tow bars + regulatory Move from brown bricks + master to clicks and ticks (web based)
H Accommodation and food services	Maintenance/repair/upgrades eg. for new technology ICT Engineering if repurposed. Compliance checks (fire/seismic, etc.) Supports compliance activities, operating systems Student workers Overseas immigrant engineers
I Transport, postal and warehousing	Significant contribution through all phases (full life cycle) strategy/ concept/ design/ development/ procurement/ build/ maintain/ operate/ decommission/ monitor/ asset management/ research/ policy Safety, systems management, compliance, safety in design, health and safety Air transport control – operating, maintenance Asset management

ANZSIC industry	Contribution of engineers/engineering
	Engineers will facilitate the creation + maintenance/operation of related infrastructure of support systems, but are unlikely to be directly involved in this "industry" code
J Information media and telecommunications	Engineers will be directly represented in this industry, and also will facilitate and support through consulting professional services, through a broad range of disciplines (eg. telecommunications, mechanical/electrical, civil, structural) and at a range of tertiary qualifications (BE (Hons) – NZDE etc.) + PhD's
K Financial and insurance services	Engineers will be directly involved in areas of risk, assurance, liability, analytics + system/software design. They will also be involved in the facilitation of supporting infrastructure NB - Many "Engineers by training" (ie. BE (Hons)) will be deployed in this industry based on "skillset + capability in "non-Engineering" roles
L Rental, hiring and real estate services	Probably limited direct involvement in this industry, but significant consulting professional services, operations + maintenance facilitating outcomes related to the physical assets in particular.
M Professional, scientific and technical services	Engineering consultancies - possibly 10-15k [percentage of engineers 30-50 percent Academic staff, research, design, innovation, advisory services, management, testing
N Administrative and support services	Not significant
O Public administration and safety	District engineers and planners, emergency authorities within the public, services Defence - marine engineers, electrical engineers, aero-nautical engineers, civil + structural engineers Would relate to those in regulation eg. WorkSafe, NZTA, Police, Fire and Emergency New Zealand
P Education and training	Schools – a few technology teachers, physics teachers + maths teachers will hold engineering qualifications (> or equal to L6 on NQF) Tertiary ~ 7 percent of university degree teaching in engineering similar in polytechs (L6 and L7) Almost no PTE education or ITO education at or above L6 in engineering Engineering informed teaching eg parts of architecture, ICT, industrial design, Q5, etc. Likely 10 percent of tertiary is engineering
Q Health care and social assistance	Engineering managers of hospitals/health care facilities Building services. People – probably consultants Assume: the design and build of new facilities falls into construction. Medical tech falls into high tech development etc
R Arts & recreation services	Minimal – Some in heritage (structural/civil/mechanical) Some in artistic (structural/materials/mechanical, electronic) ie Weta workshops Some in sport (structural/civil/mechanical) include recreational plant (certification) ski lifts Gambling – insignificant
S Other services	Only repair and maintenance, including household repairs (ie structural), planning engineer, etc. No engineers involved in personal and private households

Table 4 Occupations – descriptions from workshop

ANZSCO code	Occupation title	Proportion/Percentage that are engineers	Remuneration comments
1	MANAGERS		
133211	Engineering Manager	> or equal to 90 percent	150k
2	PROFESSIONALS		
23	Design, Engineering, Science and Transport Professionals		
231212	Ship's Engineer	0.8	60k-180k
233111	Chemical Engineer	90-95 percent	100-120k
233112	Materials Engineer	0.7	100k
233211	Civil Engineer	0.8	100-120k
233212	Geotechnical Engineer	>80 percent	100k
233214	Structural Engineer	~100 percent	100k
233215	Transport Engineer	85 percent	$100-120k
233311	Electrical Engineer	70-90 percent qualified	Graduate 50k, Senior 120k, Principal 200k
233411	Electronics Engineer	70-90 percent	Graduate 50k, Senior 120k, Principal 200k
233511	Industrial Engineer	70-90 percent	Graduate 50k, Senior 120k, Principal 200k
233512	Mechanical Engineer	70-90 percent	Graduate 50k, Senior 120k, Principal 200k
233513	Production or Plant Engineer		
233611	Mining Engineer (excluding Petroleum)	0.95	180-200k
233612	Petroleum Engineer	0.95	150k
233911	Aeronautical Engineer	100 percent [BE (Hons)]	100k (+-50k)
233912	Agricultural Engineer	< 20 percent [from no qualifications to degree BApplSc (Ag Eng) or NZDE or BE (Hons)	100k
233913	Biomedical Engineer	100 percent [BE (Hons) "Biomed" "Elec"	100k (+-30k)
233914	Engineering Technologist	100 percent NZDE or B Eng Tech or higher	80k (+-20k)
233915	Environmental Engineer	100 percent [BSc or BE (Hons)]	100k (+-20k)
233999	Engineering Professionals nec		

ANZSCO code	Occupation title	Proportion/Percentage that are engineers	Remuneration comments
26	ICT Professionals		
261313	Software Engineer	1	200k+
263111	Computer Network and Systems Engineer	1	120k
263211	ICT Quality Assurance Engineer	80-90 percent	100k
263212	ICT Support Engineer		
263213	ICT Systems Test Engineer		
263299	ICT Support and Test Engineers nec		
263311	Telecommunications Engineer	80-100 percent	82-85k
263312	Telecommunications Network Engineer	80-100 percent	82-85k
3	TECHNICIANS AND TRADES WORKERS		
312211	Civil Engineering Draftsperson	Unlikely to be engineers	60k
312212	Civil Engineering Technician	Unlikely to be engineers. 5-10 percent have BE	55-60k
312311	Electrical Engineering Draftsperson	Unlikely to be engineers	60k
312312	Electrical Engineering Technician	Unlikely to be engineers. 5-10 percent have BE	55-60k
312411	Electronic Engineering Draftsperson	Unlikely to be engineers	60k
312412	Electronic Engineering Technician	Unlikely to be engineers. 5-10 percent have BE	55-60k
312511	Mechanical Engineering Draftsperson	Unlikely to be engineers	60k
312512	Mechanical Engineering Technician	Unlikely to be engineers. 5-10 percent have BE	55-60k
312999	Building and Engineering Technicians nec		
313212	Telecommunications Field Engineer	80 percent polytech	55k
323111	Aircraft Maintenance Engineer (Avionics)	100 percent NECE equipped	60k
323112	Aircraft Maintenance Engineer (Mechanical)	100 percent NECE equipped	60k
323113	Aircraft Maintenance Engineer (Structures)	100 percent NECE equipped	60k
323411	Engineering Patternmaker	0	60k
7	MACHINERY OPERATORS AND DRIVERS		
712311	Engineering Production Worker	~20 percent	55k

ANZSCO code	Occupation title	Proportion/Percentage that are engineers	Remuneration comments
8	LABOURERS		
839111	Metal Engineering Process Worker	Very few	55k

Appendix B Restrictions

This report has been prepared solely for the purposes stated herein and should not be relied upon for any other purpose. We accept no liability to any party should it be used for any purpose other than that for which it was prepared.

This report is strictly confidential and (save to the extent required by applicable law and/or regulation) must not be released to any third party without our express written consent which is at our sole discretion.

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We have not independently verified the accuracy of information provided to us, and have not conducted any form of audit in respect of the organisation for which work is completed. Accordingly, we express no opinion on the reliability, accuracy, or completeness of the information provided to us and upon which we have relied.

The statements and opinions expressed herein have been made in good faith, and on the basis that all information relied upon is true and accurate in all material respects, and not misleading by reason of omission or otherwise.

The statements and opinions expressed in this report are based on information available as at the date of the report.

We reserve the right, but will be under no obligation, to review or amend our report, if any additional information, which was in existence on the date of this report, was not brought to our attention, or subsequently comes to light.

This report is issued pursuant to the terms and conditions set out in our contract dated 11 February 2019.

Engineering is…

‘Applying an evidence-based approach to a problem, then designing, implementing and maintaining a solution.’

Workshop, senior engineer