write@uni
www.auckland.ac.nz/writeatuni

Annotated Engineering Research Report (Stage 1)

Contents

1. Annotated example of an Engineering Research Report based on an individual research project.
2. Guidelines about report writing, with examples from the Engineering Research Report.

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Illustration of a hen sitting on an egg

Figure 1: Brown hen near white egg on nest (Burrell, 2016)

Here, the writer included two figures that were illustrative of the focus of his research. The figures are not included in this version of the report for copyright reasons. Note that each **Figure** has a **title** to describe it. Titles for figures are placed below each figure.

Illustration of a soybean field

Figure 2: Soybean field (MachineFinder, 2014)

PROTEIN SOURCES IN NEW ZEALAND

As this example shows, the **title** of an engineering report should be concise and informative so that the reader can quickly discover what the report is about (Silyn-Roberts, 2012).

COURSE NAME Research Report

Student name and ID

Note the inclusion of the **author's name** and the **date of submission** right at the beginning of the report. This information together with the title and the course name is placed on the title page.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

The **Abstract** is placed on a page by itself, immediately after the title page. Some reports begin with an Executive Summary rather than an Abstract. Check with your lecturer what is expected.

The **Abstract** gives the reader the opportunity to understand **what** the report is about, **why** it was written, how information was obtained, and **what** was found.

Abstract

With New Zealand's population expected to reach 6.5 million by 2068, the sustainability, efficiency and ethical acceptability of chicken as a protein source in New Zealand is in question. This report evaluates the suitability of soybean farms as an alternative source of protein production in New Zealand to broiler farms. The information required was obtained through a literature search. To facilitate the comparison of farms, resource use per kilogram of digestible protein of a typical chicken farm and an equivalent soybean farm were considered. Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than typical chicken farms and 0.563L/kg less water p.a. Also, soybean farms produce 7.49kg/kg less CO_2 equivalent gases p.a. but use 3.98×10^{-4} Ha/kg more land area. Despite their greater efficiency, and ethical acceptability, New Zealand's temperate climate makes it not economically viable to completely replace broiler farms in New Zealand. Soybean plants, however, could still be used in a crop rotation from November to March in the North Island.

The first sentence provides a **broad introduction** to the topic of the research and **highlights the problem** the report will seek to address.

The second sentence the writer outlines the **purpose** of the report and what it is seeking to achieve.

The next two sentences summarise the approach taken to collect data. Note the switch to the **passive voice** in the **past tense**. 'The information required was obtained ...'. Using the passive enables the writer to focus on the **result of the action** rather than **who** did it. Otherwise, in the **active voice** this would have said, "I obtained the information through a literature search".

The fifth and sixth sentences provide a summary of the **results**. Note the switch back to the **active voice** here. Using the active voice enables the writer to focus on the **doer** or **performer** of the action ('Results" and "soybean farms"). The **present tense** is used to outline established facts.

Here the writer **links the argument** by using the **transition signal** "however", which indicates a contrasting thought.

The final two sentences provide the **conclusions** of the report. Note that the **active voice** and **present tense** are used to present these.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

The **Table of Contents** follows the Abstract and enables the reader to get an **immediate overview** of **what** is included in the report and **where** each part is located.

Creating a **Table of Contents** can be done easily and automatically if you use **Heading Styles** as you write your report in Word. When you are ready to create your Table of Contents, you just need to click on 'Table of Contents' in the References tab.

Table of Contents

*Please note that these page numbers do not correspond to the page numbers used in this annotated version of the Report

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

The **List of Figures**, **Tables** and **Equations** follows the Contents page. The List of Figures always goes before the List of Tables. As this example shows, these are an important part of engineering reports. Each is **numbered sequentially**, with a brief title and listed with its page number. When considering whether to use a Figure, Table or extended text, it is important to decide which communicates your message most clearly.

LIST OF FIGURES

A variety of **Figures** are used in the form of **photos, diagrams** and **graphs** to help the reader to understand the study topic and results.

LIST OF TABLES

Two **Tables** are used as they are an **efficient means of presenting information**. As illustrated here, Tables can be used to compare chicken and soybean farms.

If a report has **equations** a description of each equation should be included after the List of Figures and List of Tables.

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1.0 INTRODUCTION

With New Zealand's population expected to reach 6.5 million by 2068 (Statistics New Zealand, 2017), it is important that domestic food production remains efficient, sustainable and ethically acceptable. Also, with the average New Zealander consuming 37.5kg of chicken each year, chickens are the most greatly consumed poultry in New Zealand (PIANZ, 2018). It is thus important that the poultry industry is efficient with its use of resources, or a more efficient protein-alternative is found.

Animal, plant and insect-based sources, as well as lab-grown sources are some of the alternative protein sources under investigation. Soybean farms have already proven successful in other countries, with 77.5 million acres being planted in the USA in 2009 (Ash, 2017). Additionally, soybeans have a similar nutritional composition to chicken (Johnson, White, & Galloway, 2008), so may serve as a more humane alternative.

The objective of this report is to evaluate soybean farms as an alternative form of protein production to broiler farms. The scope includes an analysis of the benefits and challenges arising from energy, water and land usage and the CO_2 equivalent production

The **Introduction** gives the reader the opportunity to understand **what** the report is about, **why** it was written, and **how** the information was found.

The first sentence provides a **broad introduction** to the topic of the research and highlights the importance of it.

The second and third sentences **identify the need for the research** and introduce the problem that needs to be solved.

Note the expert way in which the **writer's opinion** about the importance of the research is signalled here. By using the word "important" the writer is signalling that there is a definite need for this report. The word "vital" or "imperative" could have been used to make an even stronger statement.

Note the way in which the writer skilfully develops a **coherent and logical argument** in this paragraph. The paragraph begins with a **topic sentence**, which gives a general overview of the various alternatives to chicken farming. The following two sentences **narrow down the focus of the study** (to using soybeans as an alternative to chicken) and then provide the **rationale** for this farming approach ("as a more humane alternative".

Note the effective use of the **transition signal** "additionally" which indicates that the writer is going to discuss another favourable aspect of soybean farms.

Here, the writer clearly outlines the **objective** of the report. Note the language used to do this: "The objective of this report is to …".

The writer then provides the **scope** of the report. Because there is so much that could be covered in such a report, the writer clarifies exactly what will be investigated.

Annotation key

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of both types of farm. Consideration is given to consumer satisfaction, the efficiency of production of chicken and soybeans, and adopting an ethical approach. Limitations include reliance on secondary data, the two month time-frame allocated and difficulty finding New Zealand-based data.

Outlining the **limitations** of this very small-scale study is important so that the reader (the marker) does not have unrealistic expectations of what is presented.

Here, the writer **elaborates** on what will be considered in the report.

1.1 Definitions

Typical Chicken Farm – These farms produce 402,500 chickens/year, assuming the average chicken production per farm is the same as in Kentucky (from where reliable information is most easily accessible) (University of Kentucky, 2018).

Equivalent Soybean Farm – The total digestible protein production of all equivalent soybean farms is equivalent to the total digestible protein production of all typical broiler farms in New Zealand. Dividing the total protein production amongst soybean farms of the land area 205.4 Ha – the mean land area of grain farms in New Zealand (Land Information New Zealand, 2012) – gives an 'equivalent soybean farm'. Table 1 summarises the key characteristics of each type of farm:

Providing **definitions of key terms** is important so that the writer can avoid ambiguity and ensure that the reader knows what is meant by particular terms and what assumptions are being made. Sometimes, rather than providing a separate 'Definitions' section in a report like this one, definitions of key terms are given in the body of a report the first time a term is used. Check with your lecturer if you are unsure which approach you should use.

See how the writer **introduces the Table** in the sentence immediately before it appears. Alternatively, the writer could have said, "See Table 1 for a summary of the key characteristics of each farm-type".

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Table 1 – Key characteristics of a typical chicken farm and an equivalent soybean farm

Characteristic	Typical Chicken Farm	Equivalent Soybean Farm
Number of farms required to meet demand of New Zealand consumers	180 (Appendix B ii)[a]	65 (Appendix D ii)[f]
Digestible protein production per annum (kg)	175,000 (Appendix B iii)	488,000 (Appendix D iii)
Energy usage per annum (MJ)	15,100,000 (Appendix C i)[b]	2,340,000 (Appendix E i)[g]
Water usage per annum (L)	98,400 (Appendix C iii)[c]	0 (Appendix E iii)[h]
Land area (Ha)	3.98 (Appendix C iv)[d]	205.4 (Appendix E iv)
CO_2 equivalent production per annum (kg)	1,400,000 (Appendix C ii)[e]	270,000 (Appendix E ii)

To provide a **comparative summary** of chicken and soybean farms, the writer uses **superscript letters** to refer the reader to the key assumptions for each calculation and places the **name of the relevant Appendix in brackets** after each number. Detailed calculations for each figure are provided in the Appendices.

Key assumptions for each calculation:

In this section, the writer provides information about each assumption referred to with a **superscript letter** the Table above. Because each assumption is from a different part of the Table, they do not need to be connected here to one-another, but rather can be presented in the form of a list of separate sentences.

[a] The average production of chickens per farm, per year is the same in New Zealand as in Kentucky (University of Kentucky, 2018).

[b] The energy requirements to produce broiler chickens is the same as in 2008 (Pelletier, 2008).

[c] The average water consumption is 244.375L per 1000 birds per annum (University of Arkansas Division of Agriculture, 2009).

[d] All farms adopt the minimum best practice recommendations of 30 kg live chicken mass/m^2 (Ministry for Primary Industries, 2018), the proportion of chicken produced on free-range farms in New Zealand is the same as Australia (Australian Chicken Meat Federation Inc., 2013), all free range

Note that for each of the key assumptions, the writer provides a **reference to the literature** from where the information came. Doing this is essential for ensuring the credibility of any literature-based research. **APA referencing style** is used in this report.

chickens have access to a range 1.5x the floor area of the barn as required for SPCA accreditation (PIANZ, 2018) and each farm is only comprised of the land area available for the chickens to roam.

See how the writer competently makes **comparisons with previous research** by using the phrase "is the same as".

[e] The CO_2 equivalent production per tonne of broiler poultry is the same as in 2008 (Pelletier, 2008).

[f] Soybean productivity is maintained at the highest observed productivity in New Zealand of six tonnes/hectare (Millner & Roskruge, 2012).

[g] The average energy required to produce soybean plants is the same as in 2008 (Pelletier, N.; Arsenault, N.; Tyedmers, P., 2008).

Note that the writer uses the **simple present tense** for each assumption. This tense is used because, for the purpose of this assignment which compares chicken and soybean farms, the writer needs to assume that all prior research (NZ and international) is relevant at the current time in the NZ context.

[h] Assuming optimal irrigation levels are less than those in central Iowa, USA (Iowa is closer to the equator than New Zealand), soybean farms would require a maximum of 317mm of rainfall over a season (Dietzel, et al., 2015). As soybean plants take roughly five months to mature (Kowalski, 2018), and the lowest average rainfall over five months in New Zealand is 343mm (in Masterton) (NIWA, 2010), soybean farms should require no irrigation on average.

Note how the writer uses **brackets** to provide **additional relevant information** for the purpose of comparison.

The above assumptions were made to allow the use of outdated and international data where no recent data was available for New Zealand.

In this concluding sentence, the writer importantly **outlines** the reasons for **each of these assumptions**.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

2.0 Discussion

2.1 Benefits

2.1.1 Energy consumption, water consumption and carbon dioxide equivalent production

Note the use of **numbering** at different levels to indicate the connection between each of the headings and their respective importance.

Table 2: Resource use of a typical chicken farm and an equivalent soybean farm per kg of digestible protein production

Resource	Chicken Farm	Soybean Farm	Chicken Farm – Soybean
Energy usage per annum (MJ/kg)	86.2 (Appendix C i)	5.00 (Appendix E i)	81.2
Water usage per annum (L/kg)	0.563 (Appendix C iii)	0 (Appendix E iii)	0.563
Land area (Ha/kg)	$2.27 \times 10^{/0}$ (Appendix C iv)	$4.21 \times 10^{/1}$ (Appendix E iv)	-3.98×10^{-4}
CO_2 equivalent production per annum (kg(CO_2)/kg(digestible protein))	8.04 (Appendix C ii)	0.553 (Appendix E ii)	7.49

The key assumptions are identical to the corresponding assumptions in Table 1.

Conciseness is an important feature of academic writing. Here, to be concise, the writer has **referred the reader back** to the key assumptions for Table 1.

See how the writer **interprets the content of the Table.** Describing what you place in a Table is very important as it enables the reader to follow your reasoning and understand why you have placed it there.

Soybean farms use 81.2MJ less energy, 0.563L less water and produce 7.49kg less CO_2 equivalent gas per kg of digestible protein, per annum as seen in Table 2. As a result, soybean farms are more economical and environmentally-friendly to run than broiler farms.

Here the writer **skilfully links the argument** by using the **transition signal** "As a result". This phrase prefaces the main point about the benefits of soybean farms.

2.1.2 Ethics and morality

See how a special section on "**ethics**" is included here because **ethical issues** (e.g., animal health and genetic modification) need to be considered when decisions are made about farming approaches.

The ethical acceptability of raising broiler chickens for slaughter is the subject of an ongoing debate. Although chicken farmers claim "Animal health, welfare and

Annotation key

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well-being are given the highest priority" (PIANZ, 2018), many people believe the "wrongful mistreatment of animals" (Chignell, Cuneo, & Halteman, 2016) to be commonplace in animal farms. Regardless of the conditions broiler chickens are raised in, the consumption of chicken remains a non-permissible moral issue to some (Chignell, Cuneo, & Halteman, 2016).

See how the writer skilfully uses **quotations** here to **strengthen the argument**. It is important not to overuse quotations in academic writing, however, but just use them for a particular purpose, such as **strengthening a claim**. Also, when using quotations, check your referencing style guidelines to see whether or not the **page number** of the quotation needs to be included.

See how the writer expertly **sums up the argument** in this paragraph about the ethical reasons why chicken farming is problematic.

As soybeans are sourced from plants, the ethical issues associated with their consumption are reduced; genetic modification of soybean plants may present an ethical issue for some, however (Bawa & Anilakumar, 2013). The use of plants rather than animals increases the likelihood that New Zealand consumers will overall be more morally satisfied.

Here the writer indicates a contrasting thought by using the **transition signal** "however". If the writer had wanted to give more emphasis to this contrasting idea, this word could have been placed earlier - before "genetic" or after "may".

2.1.1 Consumption efficiency

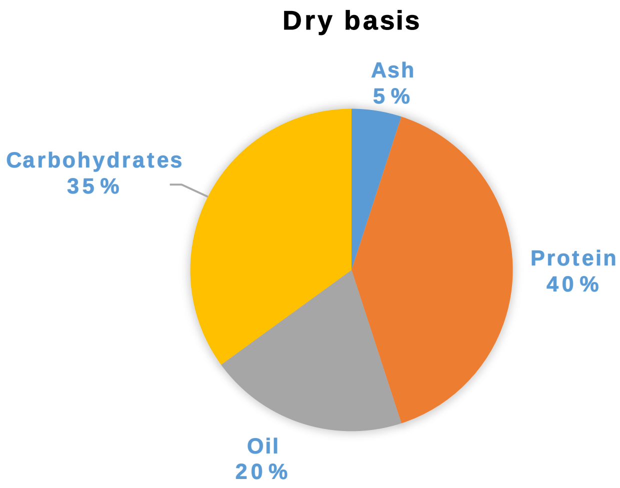
Soybeans have a greater nutritional input per unit consumed than chicken. The average person consumes 21kg of chicken per annum (Appendix A iii) while only 16.4kg of soybeans must be consumed per annum to receive an equivalent amount of digestible protein (Appendix D i). This is due to the high protein content of soybeans (40% of dry mass as seen in Figure 3) compared to chicken (31.0% (Smetana, Mathys, Knoch, & Heinz, 2015).

Note the way in which the writer refers the writer to the **Appendix,** where the calculation is written in full. Placing the equations in the Appendix **enables the writer to be concise** when providing evidence for the claim being made.

Note the way in which the writer refers to the **Figure** below by its **name** (Figure 1). Each time a Figure or Table appears, the writer directs or "signposts" to the reader what they need to look for in the Figure of Table to follow. The present tense is always used to do this.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary



Figures provide a **pictorial representation** of what is being described (in this case, the composition of soybeans). Figures enable the writer to present their findings **concisely** and **clearly**.

Figure 3: Nutrient composition of soybeans (Preece, Hooshyar, & Zuidam, 2017)

Soybean production wastes less nutrients than chicken production. As seen in Figure 4 below, approximately 10% of energy is passed to the next trophic level (Drayer, 2016).

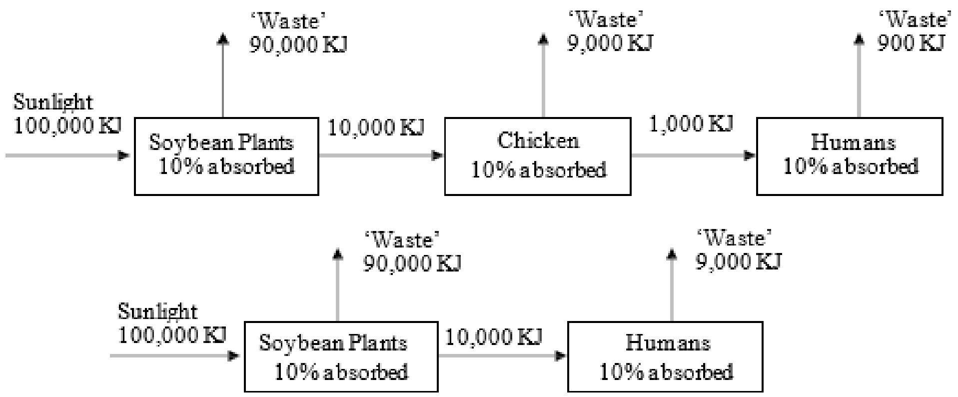


Figure 4: Comparison of energy efficiency of soybean and chicken consumption

Removing chickens from the energy equation would result in humans receiving 1% of the total energy input, rather than 0.1% currently. As 98% of soybeans produced are used in animal feed (Johnson, White, & Galloway, 2008), direct consumption would significantly decrease the effort put into producing chemical-potential energy that would otherwise be effectively wasted.

Note that each **Figure** has a **title to describe it.** In APA style, titles for figures are placed below where figures appear, whereas titles for tables are placed above.

See how the writer uses the **'boosters'** or **'intensifiers'** "significantly" and "effectively" to make much stronger claims about the benefits of soybean farming.

Annotation key

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2.2 Challenges

2.2.1 Land area requirements

Soybean farms require 3.98x10^{-4} Ha more land area than broiler farms per kilogram of digestible protein produced, as seen in Table 2. A total of 13,400 13,400 Ha (Appendix E iv) is required to make all 65 (Table 1) required soybean farms. It will be a challenge to find, purchase and maintain such a significant portion of land.

See how the **writer clearly and concisely points** the reader to the **sources** of the data being referred to in the Tables and Appendices.

Outlining the **Challenges** forms an important part of this report so that the writer is able to provide a realistic picture of the feasibility of what they propose (in this case, soybean farms). Note how the writer uses separate subheadings for each challenge. Doing this enables the writer to structure the argument around each challenge.

2.2.2 New Zealand Climate

New Zealand's climate presents the greatest challenge to the viability of soybean farms. Most varieties of soybean plants have an optimum temperature range of 20 – 25°C (Martin, 1988).

The only five-month period (average time to maturity of soybean crops) (Kowalski, 2018) within which New Zealand experiences mean maximum temperatures in this range is from November to March (with minimum temperatures fluctuating between 9 - 14°C) (NIWA, 2010). Furthermore, these temperatures only occur in the North Island (NIWA, 2010). These findings mean that soybeans could only be grown near their optimum rate in the central North Island for a period of five months, which means that they are not economically viable for most of the year (Millner & Roskruge, 2012).

2.2.3 Consumer satisfaction

Soybean-based meat substitutes frequently aim to replicate the taste and texture of meat (Porter, 2003), and consumers are often dissatisfied when this aim is not met. Although soybeans can be extruded with high moisture, giving a texture similar to chicken (MacDonald, Pryzbyszewski, & Hsieh, 2009), the current negative perceptions held by some consumers about soy-based substitutes will need to be overcome to ensure successful uptake (Simon, 2016).

Also of concern is the reality that soybeans are considered one of the "Big 8" most allergenic foods (Ustunol, 2014). Consequently, a large proportion of the population will be unable to consume soy-based foods.

Annotation key

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3.0 Conclusions

The **Conclusions** section gives the writer the chance to sum up the main findings of the research.

Equivalent soybean farms use 81.2MJ/kg less energy and 0.563L/kg less water than typical chicken farms. Also, they produce 7.49kg/kg less CO_2 equivalent gases than comparable chicken farms. Additionally, soybeans are considered to be more ethically acceptable for consumption. Overall, 10x more input energy is received by the human consumer, and only 16.4kg of soybeans must be consumed for every 21kg of chicken meat to receive an equivalent quantity of protein. However, soybean farms require $3.98x10^{-4}$ Ha/kg more area than chicken farms, and many people are allergic to soybean-based foods, while others perceive soy substitutes negatively.

In this first paragraph **by specifically referring to relevant data**, the writer has provided a very informative **summary** of the **main research findings** and the rationale why soybean farms are preferable to chicken farms.

The writer has succeeded in providing a **balanced perspective** in his **argument** here, by presenting specific data outlining three key barriers to soybean farming.

New Zealand's temperate climate provides the greatest barrier to the success of soybean farms. The lack of economic viability for most of the year makes it unlikely that soybean farms can completely replace broiler farms in New Zealand. However, North Island farmers could grow soybean crops during the summer season, rotating to other crops during colder seasons. In this way, soybean farms could partially replace broiler farms in New Zealand.

In the second paragraph the writer continues to outline the **barriers to** soybean farming. Since the temperature at which soybeans need to grow for maximum economic viability is mentioned earlier, the writer could have further strengthened the argument by including it here.

The writer **skilfully concludes** the report by making a recommendation about the way forward for soybean farming in NZ. This recommendation entails a partial move to soybean farming and takes into account both the favourable and unfavourable reasons for the adoption of soybean farming in NZ.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

4.0 References

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Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

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Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

It is usual practice to put **non-essential information,** which provides further clarification of a point in an **Appendix**. In this case, the writer has provided evidence for the information provided in the Tables and Assumptions section, on which the argument was based. **Appendices** are **sequentially labelled** with letters of the alphabet. Placing the information here means that unnecessary space is not used within the body of a paper (Bates College, 2011).

5.0 APPENDICES

Appendix A: Total chicken protein consumed by New Zealanders

i) Total mass of chicken meat consumed in New Zealand

- Live mass of chicken consumed by the average New Zealander per annum = 37.5kg/year (PIANZ, 2018).
- Population of New Zealand = 4,831,000 persons (Statistics New Zealand, 2018).

$$\begin{aligned}&\textit{Total live weight chicken consumption per annum}\\&= \textit{chicken consumption per person per annum} \times \textit{number of people}\\&= 37.5\frac{kg}{person \times year} \times 4{,}831{,}000\ persons.\\&= 181{,}162{,}500\frac{\text{kg}}{\text{year}}.\end{aligned}$$

ii) Total digestible protein consumed by New Zealanders from chicken

- Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A i).
- On average, 56.0% of live weight chicken is edible (Pelletier, 2008).
- Protein content of live chicken weight is 31.0% (Smetana, Mathys, Knoch, & Heinz, 2015).
- The Protein Digestibility Corrected Amino Acid Score (PDCAAS) for chicken is 1.00 (Smetana, Mathys, Knoch, & Heinz, 2015).

$$\begin{aligned}&\textit{Total digestible protein consumed by New Zealanders from chicken per annum}\\&= \textit{live weight chicken consumption per annum}\\&\times \textit{edible \% of live weight} \times \textit{protein \% of live weight}\\&\times \textit{PDCAAS for chicken}\\&= 181{,}162{,}500\frac{kg}{year} \times \frac{56\%}{100\%} \times \frac{31\%}{100\%} \times 1\\&= 31{,}449{,}810\frac{kg}{year}\\&= 31{,}400{,}000\frac{kg}{year}(3sf)\end{aligned}$$

Assuming no protein content is lost during processing.

iii) Mass of chicken consumed by average New Zealander per annum

- Live mass of chicken consumed by the average New Zealander per annum = 37.5kg/year (PIANZ, 2018).
- On average, 56.0% of live weight chicken is edible (Pelletier, 2008).

$$\begin{aligned}&\textit{Average consumption of chicken mass per person per annum}\\&= \textit{live weight chicken consumption per person per annum}\\&\times \textit{edible \% of live weight}\\&= \frac{37.5kg}{year} \times \frac{56\%}{100\%}.\\&= 21\frac{kg}{person \times year}\end{aligned}$$

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Appendix B: Characteristics of a typical chicken farm

i) Total yearly consumption of chickens

- Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A i).
- Average chicken mass = 2.5kg (Bartov, 2010).

$$\begin{aligned}&\textit{Total number of chickens consumed in NZ per annum}\\&= \frac{\textit{total live weight chicken consumption per annum}}{\textit{average chicken mass}}\\&= \frac{181{,}162{,}500 \frac{kg}{year}}{2.5 \frac{kg}{chicken}}\\&= 72{,}465{,}000 \frac{chickens}{year}\end{aligned}$$

ii) Number of typical chicken farms required

- Total number of chickens consumed in NZ per annum = 72,465,000 chickens (Appendix B i).
- Assume the average production of chickens per farm, per year is the same in New Zealand as in Kentucky (from where reliable information is most available) = 402,500 chickens/farm/year (University of Kentucky, 2018).

$$\begin{aligned}&\textit{Number of 'typical' chicken farms required}\\&= \frac{\textit{total number of chickens consumed in NZ per annum}}{\textit{number of chickens per farm per annum}}\\&= \frac{72{,}465{,}000 \frac{chickens}{year}}{402{,}500 \frac{chickens}{farm \times year}}\\&= 180.037\ farms\\&= 180\ farms\ (3sf)\end{aligned}$$

As New Zealand has around 180 farms (PIANZ, 2018), this estimation is reasonable.

iii) Digestible protein production by each typical chicken farm

- Total digestible protein consumption per annum = 31,449,810 kg/year (Appendix A ii).
- Number of typical chicken farms = 180.037 (Appendix B ii).

$$\begin{aligned}&\textit{Digestible protein production by each farm per annum}\\&= \frac{\textit{total digestible protein consumption per annum}}{\textit{number of typical chicken farms}}\\&= \frac{31{,}449{,}810 \frac{kg}{year}}{180.037\ farms}\\&= 174{,}685.26 \frac{kg}{farm \times year}\\&= 175{,}000 \frac{kg}{farm \times year}\ (3sf)\end{aligned}$$

Assuming domestic chicken production = chicken consumption so as to meet domestic demand.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Appendix C: Resource usage of a typical farm

i) Energy use

- 14,959 MJ used to produce 1 tonne of broiler poultry (Pelletier, 2008).
- Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A i).
- Number of typical chicken farms = 180.037 farms (Appendix B ii).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg/(farm x year) (Appendix B iii).

$$\begin{aligned}
&\textit{Energy consumption of a typical chicken farm per annum}\\
&= \textit{energy consumption per mass of chicken produced}\\
&\times \frac{\textit{total live weight chicken consumption per annum}}{\textit{number of typical chicken farms}}\\
&= 14{,}959\frac{MJ}{t} \times \frac{181{,}162{,}500\frac{kg}{year}}{180.037\ farms} \times \frac{1t}{1{,}000kg}\\
&= 15{,}052{,}493.75\frac{MJ}{farm \times year}.\\
&= 15{,}100{,}000\frac{MJ}{farm \times year}\ (3sf)
\end{aligned}$$

$$\begin{aligned}
&\textit{Energy consumption of a typical chicken farm per kg of digestible protein}\\
&= \frac{\textit{Energy consumption of a typical chicken farm per annum}}{\textit{digestible chicken produced by a typical chicken farm per annum}}\\
&= \frac{15{,}052{,}493.75\frac{MJ}{year}}{174{,}685.26\frac{kg}{year}}\\
&= 86.2\frac{MJ}{kg}\ (3sf)
\end{aligned}$$

ii) Carbon dioxide production

- 1395 kg of CO_2 equivalent per tonne of broiler poultry (Pelletier, 2008).
- Total live weight chicken consumption per annum = 181,162,500 kg (Appendix A i).
- Number of typical chicken farms = 180.037 (Appendix B ii).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg/(farm x year) (Appendix B iii).

$$\begin{aligned}
&CO_2\ \textit{equivalent production of a typical chicken farm per annum}\\
&= CO_2\ \textit{equivalent production per mass of chicken produced}\\
&\times \frac{\textit{total live weight chicken consumption per annum}}{\textit{number of typical chicken farms}}\\
&= 1{,}395\frac{kg}{t} \times \frac{181{,}162{,}500\frac{kg}{year}}{180.037\ farms} \times \frac{1t}{1{,}000kg}\\
&= 1{,}403{,}718.75\frac{\text{kg}}{\text{year} \times \text{farm}}\\
&= 1{,}400{,}000\frac{\text{kg}}{\text{year} \times \text{farm}}\ (3sf)
\end{aligned}$$

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

$$CO_2\ equivalent\ production\ of\ a\ typical\ chicken\ farm\ per\ kg\ of\ digestible\ protein$$
$$= \frac{CO_2\ equivalent\ production\ of\ a\ typical\ chicken\ farm\ per\ annum}{digestible\ chicken\ produced\ by\ a\ typical\ chicken\ farm\ per\ annum}$$
$$= \frac{1{,}403{,}718.75 \frac{\mathrm{kg}(CO_2)}{year}}{174{,}685.26 \frac{kg(digestable\ protein)}{year}}$$
$$= 8.04\ \frac{kg(CO_2)}{[illegible]}\ (3sf)$$

iii) Water usage

- Water consumption varies based on age and time of year (Poultry Hub, 2018). Assume average water consumption is 244.375L per 1000 birds (University of Arkansas Division of Agriculture, 2009).
- Number of chickens per farm per annum = 402,500 chickens (University of Kentucky, 2018).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg/(farm x year) (Appendix B iii).

$$Water\ usage\ of\ a\ typical\ chicken\ farm\ per\ annum$$
$$= water\ usage\ per\ chicken \times\ number\ of\ chickens\ per\ farm\ per\ annum$$
$$= 244.375 \frac{L}{1000\ chickens} \times\ 402{,}500\ \frac{chickens}{farm\ \times\ year}$$
$$= 98{,}360.9365 \frac{L}{farm\ \times\ year}$$
$$= 98{,}400\ \frac{L}{farm\ \times\ year}\ (3sf)$$

$$Water\ usage\ of\ a\ typical\ chicken\ farm\ per\ kg\ of\ digestible\ protein$$
$$= \frac{water\ usage\ of\ a\ typical\ chicken\ farm\ per\ annum}{digestible\ chicken\ produced\ by\ a\ typical\ chicken\ farm\ per\ annum}$$
$$= \frac{98{,}360.9365\ L}{174{,}685.26\ kg}$$
$$= 0.563 \frac{L}{kg}\ (3sf)$$

iv) Land usage

- Assume all firms are adopting the minimum best practise recommendations of 30 kg live chicken mass/m^2 (Ministry for Primary Industries, 2018).
- Assume the proportion of chicken produced on free-range farms in New Zealand is the same as Australia (10-15%) and take the average of 12.5% as an estimate (Australian Chicken Meat Federation Inc., 2013).
- Assume proportion of chicken produced on organic farms is the same as Australia: <1% (Australian Chicken Meat Federation Inc., 2013), thus ignore additional land used by these farms as it is neglibible.
- Assume all free range chickens have access to a range 1.5x floor area of the barn as required for SPCA acreditation (PIANZ, 2018).
- Total live weight chicken consumption per annum = 181,162,500 kgs (Appendix A i).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg/(farm x year) (Appendix B iii).

$$Total\ barn\ land\ area\ used\ in\ the\ broiler\ industry$$
$$= \frac{total\ live\ weight\ chicken\ consumption\ per\ annum}{chicken\ density\ in\ barn}$$
$$= \frac{181{,}162{,}500\ kg}{30 \frac{kg}{m^2}}$$
$$= 6{,}038{,}750\ m^2$$

$$\begin{aligned}&\textit{Run area used in free range chicken farms}\\&\quad= \textit{total barn area used in farms} \times \textit{\% of free range farms}\\&\quad\times \textit{run area as a proportion of barn area}\\&\quad= 6{,}038{,}750\ m^2 \times \frac{12.5\%}{100\%} \times 1.5\\&\quad= 1{,}132{,}265.625\ m^2\end{aligned}$$

$$\textit{Total land area used in the broiler industry} = \textit{barn area} + \textit{run area}$$

$$\begin{aligned}&\textit{Total land area used in the broiler industry} = 6038750\ m^2 + 1132265.625\ m^2\\&\quad= 7{,}171{,}015.625\ m^2\end{aligned}$$

$$\begin{aligned}&\textit{Land area used by an average chicken farm}\\&\quad= \frac{\textit{total land area used}}{\textit{number of typical chicken farms}}\\&\quad= \frac{7{,}171{,}015.625\ m^2}{180.037\ \textit{farms}}\\&\quad= 39{,}830.79\frac{m^2}{\textit{farm}}\\&\quad= 39{,}800\frac{m^2}{\textit{farm}}\ (3sf)\end{aligned}$$

$$\begin{aligned}&\textit{Land area usage of a typical chicken farm per kg of digestible protein}\\&\quad= \frac{\textit{land area used by an average chicken farm}}{\textit{digestible protein produced by a typical chicken farm per annum}}\\&\quad= \frac{3.98\ Ha}{174{,}685.26\ kg \times year}\\&\quad= 2.27 \times 10^{-5}\frac{Ha}{kg \times year}\ (3sf)\end{aligned}$$

As the land is reusable for each yearly batch of chickens, answer = $= 2.27 \times 10^{-5}\frac{Ha}{kg}\ (3sf)$

Assuming the farm is only comprised of the land area available for the chickens to roam.

Appendix D: Characteristics of an equivalent soybean farm

i) Mass of soybeans required to be consumed

- 40% of a soybean's mass is protein (Preece, Hooshyar, & Zuidam, 2017).
- Proteins in soybeans have a PDCAAS of 0.9 – 0.99 depending on the method of processing (Ustunol, 2014). Assume no protein content is lost in processing thus the PDCAAS is 0.99.
- Total digestible protien produced by broiler farms per annum = 31,449,810 kg/year (Appendix A ii).
- Population of New Zealand = 4,831,000 persons (Statistics New Zealand, 2018).

Let M be the total mass of soybeans required to get the same mass of digestible protein as is consumed, in the form of chicken, by New Zealanders per annum.

$$\begin{aligned}&\textit{\% of soybean mass that is protein} \times M \times PDCAAS\\&\quad= \textit{total digestible protein production by broiler farms per annum}\end{aligned}$$

$$=> 0.4M \times 0.99 = 31{,}449{,}810\frac{kg}{year}$$

$$M = \frac{31{,}449{,}810\frac{kg}{year}}{0.396}$$

$$M = 79{,}418{,}712.12\frac{kg}{year}$$

Assuming no soybean mass is lost during harvesting, thus production of soybeans = consumption of soybeans.

$$Average\ required\ consumption\ of\ soybean\ mass\ per\ person\ per\ annum$$

$$= \frac{total\ mass\ of\ soybeans\ to\ be\ consumed\ per\ annum}{number\ of\ people\ in\ New\ Zealand}$$

$$= \frac{79{,}418{,}712.12\frac{kg}{year}}{4{,}831{,}000\ \text{persons}}$$

$$= 16.4\frac{kg}{person \times year}\ (3sf)$$

ii) Number of equivalent soybean farms required

- Assume soybean productivity is maintained at the highest observed productivity in New Zealand of 6 tonnes/hectare (Millner & Roskruge, 2012).
- Total mass of soybeans to be produced = 79,418,712.12 kg/year (Appendix D i).
- Assume the size of each farm is that of the average grain farm in New Zealand: 205.4 Ha (Land Information New Zealand, 2012).

$$Total\ land\ required\ for\ soybean\ farms$$

$$= \frac{total\ mass\ of\ soybeans\ to\ be\ produced}{mass\ production\ of\ soybean\ farms\ per\ hectare}$$

$$= \frac{79{,}418{,}712.12\ kg}{6\frac{t}{ha}} \times \frac{1t}{1000\ kg}$$

$$= 13{,}236.452\ ha$$

$$Number\ of\ typical\ soybean\ farms\ required$$

$$= \frac{total\ land\ area\ required\ for\ soybean\ farms}{land\ area\ per\ soybean\ farm}$$

$$= \frac{13{,}236.452\ ha}{205.4\frac{ha}{farm}}$$

$$= 64.4\ farms\ (3sf)$$

$$= 65\ farms$$

$$(round\ up\ to\ ensure\ enough\ protein\ production\ to\ meet\ demand)$$

iii) Digestible protein production per equivalent soybean farm

- Total digestible protien produced by broiler farms per annum = 31,449,810 kg/year (Appendix A ii) = total digestible protein produced by soybean farms per annum (by definition).
- Number of soybean farms required = 64.4 farms (Appendix D ii).

$$Mass\ of\ digestible\ protein\ production\ per\ equivalent\ soybean\ farm\ per\ annum$$
$$= \frac{total\ digestible\ protein\ production\ by\ soybean\ farms\ per\ annum}{number\ of\ soybean\ farms}$$
$$= \frac{31{,}449{,}810\ \frac{kg}{year}}{64.4\ farms}$$
$$= 488{,}351.087\frac{kg}{farm \times year}$$
$$= 488{,}000\frac{kg}{farm \times year}\ (3sf)$$

Appendix E: Resource use of an equivalent soybean farm

i) Energy use

- 1.5 – 2.3 MJ/kg of soy produced (Pelletier, N.; Arsenault, N.; Tyedmers, P., 2008). Assume energy use is the average of this range: 1.9 MJ/kg.
- Total mass of soybeans to be produced = 79,418,712.12 kg/year (Appendix D i).
- Number of equivalent soybean farms = 64.4 farms (Appendix D ii).
- Mass of digestible protein production per soybean farm per annum = 488,351.087 kg/farm/year (Appendix D iii).

$$Energy\ consumption\ of\ an\ equivalent\ soybean\ farm\ per\ annum$$
$$= energy\ consumption\ per\ mass\ of\ soybeans\ produced \times \frac{total\ mass\ of\ soybeans\ produced\ per\ annum}{number\ of\ soybean\ farms}$$
$$= \frac{1.9\ MJ}{kg} \times \frac{79{,}418{,}712.12\frac{kg}{year}}{64.4\ farms}$$
$$= 2{,}343{,}098.65\frac{MJ}{farm \times year}$$
$$= 2{,}340{,}000\ \frac{MJ}{farm \times year}\ (3sf)$$

$$Energy\ consumption\ of\ an\ equivalent\ soybean\ farm\ per\ kg\ of\ digestible\ protein$$
$$= \frac{energy\ consumption\ of\ an\ equivalent\ soybean\ farm\ per\ annum}{mass\ of\ digestible\ protein\ produced\ per\ soybean\ farm\ per\ annum}$$
$$= \frac{2{,}343{,}098.65\ \frac{MJ}{farm \times year}}{488{,}351.087\frac{kg}{farm \times year}}$$
$$= 5.00\ \frac{MJ}{kg}\ (3sf)$$

ii) Carbon dioxide production

- 190.3 – 247.7 g of CO_2 equivalent is produced per kg of soy. Assume CO_2 production is the average of this range: 219 g/kg.
- Total mass of soybeans to be produced = 79,418,712.12 kg/year (Appendix D i).
- Number of equivalent soybean farms = 64.4 farms (Appendix D ii).
- Mass of digestible protein production per soybean farm per annum = 488,351.087 kg/farm/year (Appendix D iii).

$$CO_2\ production\ of\ an\ equivalent\ soybean\ farm\ per\ annum$$
$$= CO_2\ production\ per\ mass\ of\ soybeans\ produced \times \frac{total\ mass\ of\ soybeans\ produced\ per\ annum}{number\ of\ soybean\ farms}$$
$$= 219\frac{g}{kg} \times \frac{1kg}{1000g} \times \frac{79{,}418{,}712.12\frac{kg}{year}}{64.4\ farms}$$
$$= 270{,}072.95\frac{kg}{farm \times year}$$
$$= 270{,}000\ \frac{kg}{farm \times year}\quad (3sf)$$

$$CO_2\ production\ of\ an\ equivalent\ soybean\ farm\ per\ kg\ of\ digestible\ protein$$
$$= \frac{CO_2\ production\ of\ an\ equivalent\ soybean\ farm\ per\ annum}{mass\ of\ digestible\ protein\ produced\ by\ an\ equivalent\ soybean\ farm\ per\ annum}$$
$$= \frac{270{,}072.95\ \frac{kg(CO_2)}{farm \times year}}{488{,}351.087\frac{kg(digestable\ protein)}{farm \times year}}$$
$$= 0.553\ \frac{kg(CO_2)}{kg(digestable\ protein)}\ (3sf)$$

iii) Water use

- Water use varies depending on growth stage, soil water holding capacity, and climate (primarily temperature and humidity). Assume optimal irrigation levels are the same as those in central Iowa, USA: 317mm over a season (Dietzel, et al., 2015).
- Soybean plants take roughly 5 months to mature (Kowalski, 2018).
- The only time New Zealand experiences mean max temperatures within the optimal 20 – 25°C range is from November – March and they only occur from the central North Island, north (NIWA, 2010). During this time period, the central North Island experiences a mean of 400 mm of rain (NIWA, 2010). As this is above the optimal water requirements, natural precipitation should be sufficient for the growth of soybeans in New Zealand.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Engineering Reports

Background to this engineering report

The above engineering report was written by a first year engineering student at the University of Auckland based on a literature search completed for a Research Report.

Sections of an Engineering Report

There are many different ways to structure an engineering report; the structure chosen depends on the type of report (e.g., general report, design report) (Silyn-Roberts, 2012).

Students writing this research report were required to include the following main sections in the format given: Title page, Abstract, Table of Contents, 1.0 Introduction, 2.0 Discussion, 2.1 Benefits, 2.2 Challenges, 3.0 Conclusions, 4.0 Reference list in APA style, 5.0 Optional Appendices. They were also asked to include at least one figure or table, and calculations with the values and any assumptions used explained.

Because there are several different types of engineering reports, it is vital that you follow the course guidelines about the sections that need to be included. In addition, you need to use the correct referencing style and keep within the word limit. Below is a brief overview of each section of a research report like this one based on a literature search:

Title page
The Title page takes up the first page of an engineering research report. Information placed on this page includes the title of the report, the course name, the writer's name, and the date (month, year).

Abstract
The purpose of the Abstract is to explain what the report is about, why it was written, how information was obtained, and what was found.

Table of Contents
The Table of Contents enables the reader to get an immediate overview of what is included in the report and where each part is located.

List of Figures, Tables, and Equations
The List of Figures, Tables and Equations follows the Contents page. The List of Figures is always placed first. Each Figure is numbered sequentially with a brief title and listed with its page number.

Introduction
The Introduction gives the reader the opportunity to understand the background to the report and what it is about, why it was written, and how the information was found. This section may also include the definition of key terms and the assumptions behind the data collected and calculations made.

Discussion
The Discussion of this report interprets the data identified through the literature search and outlines the benefits and challenges of what is proposed in the report (in this case, a switch to soybean farms from broiler farms). Key data are presented in tables and figures; for example, in pie and flow charts.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Conclusions
This section gives the writer the chance to sum up the main findings of the research.

References
This section comprises a list of all references referred to in the research paper.

Appendices
It is usual practice to put non-essential information, which provides further clarification of a point in an Appendix. Appendices are sequentially labelled with letters of the alphabet. Placing the information here means that unnecessary space is not used within the body of a paper (Bates College, 2011).

Distinctive language features of engineering research reports

Engineering reports have a number of distinctive language features, which are outlined below:

Parallelism
One distinctive feature of well-written engineering reports is the use of parallelism, which means that the same grammatical pattern is used in lists or comparisons. The writer sometimes uses parallelism in this report, which makes it easier for the reader to follow the argument; e.g.,

(1) The total digestible protein production of all equivalent soybean farms is equivalent to the total digestible protein production of all typical broiler farms in New Zealand.

Noun phrase	**preposition**	**noun phrase**
The total digestible protein production	of	all equivalent soybean farms
the total digestible protein production	of	all typical broiler farms in New Zealand.

(2) Animal, plant and insect-based sources, as well as lab-grown sources …

Pre-modifiers	**Head noun**
Animal, plant and insect-based	sources
lab-grown	sources

Pronoun usage
A further feature of research reports is related to the use of personal pronouns (e.g., I, he, we). Check with your lecturer whether it is appropriate to use these because in some cases they can be used. No pronouns, however, are used in this report. Rather, the writer uses passive voice to avoid any need of mentioning their role in carrying out the study; e.g.,

(1) <u>The above assumptions were made</u> to allow the use of outdated and international data where no recent data was available for New Zealand.

(2) <u>The information required was obtained</u> through a literature search.

Specialised vocabulary
Another feature of well-written research reports is that specialised vocabulary is correctly used. As you can see in the following two sentences, the writer has correctly used equations and commonly accepted abbreviations:

> Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than typical chicken farms and 0.563L/kg less water p.a..

Indeed, the writer has first written the expression "per annum" in full and subsequently just written the abbreviated form "p.a.".

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Given the importance of correctly using specialised vocabulary, you may find it useful to build a glossary and focus on learning these words so that you are familiar with their meaning, the words they collocate with, and the various forms of the word, including abbreviations.

Expressing an opinion or the author's "voice"

As you can see in the above report, it is possible for the writer to position themselves and express their opinion through their choice of language even though it is written entirely in the third person and no use of "I" is made. Indeed, as this report shows, it is possible to express your views by using words that express certainty (thus making a strong claim) or uncertainty (thus making a weak or tentative claim).

Strong claims

Strong claims are made using adverbs that have a strong meaning (e.g., significantly). These adverbs along with the adjective counterparts (e.g., significant, greatest) are sometimes referred to as "boosters" or "intensifiers". As the following example shows, when making such a claim in the report, the writer first provides evidence for the claim being made:

> As 98% of soybeans produced are used in animal feed (Johnson, White, & Galloway, 2008), direct consumption would significantly decrease the effort put into producing chemical-potential energy that would otherwise be effectively wasted.

Tentative claims

Weak or tentative claims are made by using "hedging" devices such as "perhaps" or "may". Hedging is a way that writers can express uncertainty, avoid drawing unjustified conclusions and acknowledge that they are not experts. The following example illustrates the writer using the modal verb "may" to indicate that there is a possibility that there could be ethical issues around the use of soybean plants which have been genetically modified:

> As soybeans are soured from plants, the ethical issues associated with their consumption are reduced; genetic modification of soybean plants may present an ethical issue for some, however (Bawa & Anilakumar, 2013).

The extent to which strong or weak claims are made in reports often depends on the topic and the room for interpretation within this.

Another way to express the writer's voice

Although not done in this report, it is possible for writers to make subjective comments when interpreting the data in the Discussion by using words (e.g., obvious[ly], surprising[ly], ideal[ly]) and phrases (e.g., it is useful to note, in particular).

Verb usage

This engineering report is almost entirely written in the present tense. A switch is made to the past tense is to report on the methodology used (see Abstract), and to sum up the rationale for each assumption (see Introduction).

Verb tenses

Abstract

The present tense is used to:

(1) Describe the problem the report is exploring
With New Zealand's population expected to reach 6.5 million by 2068, the sustainability, efficiency and ethical acceptability of chicken as a protein source in New Zealand is in question.

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

(2) Outline the purpose of the report and what it is seeking to achieve
This report evaluates the suitability of soybean farms as an alternative source of protein production in New Zealand to broiler farms.

(3) Summarise the results
Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than typical chicken farms and 0.563L/kg less water p.a.

(4) Outline the conclusions
Despite their greater efficiency, and ethical acceptability, New Zealand's temperate climate makes it not economically viable to completely replace broiler farms in New Zealand.

The past tense is used to:

(1) Report on the methodology used
The information required was obtained through a literature search.

Introduction

The present tense is used throughout the introduction (apart from the last sentence) to:

(1) Give a broad introduction to the topic
With New Zealand's population expected to reach 6.5 million by 2068 (Statistics New Zealand, 2017), it is important that domestic food production remains efficient, sustainable and ethically acceptable.

(2) Highlight the need for the current research
It is thus important that the poultry industry is efficient with its use of resources, or a more efficient protein-alternative is found.

(3) State the purpose of the current research
The objective of this report is to evaluate soybean farms as an alternative form of protein production to broiler farms.

(4) Outline the scope of the research
The scope includes an analysis of the benefits and challenges arising from energy, water and land usage and the CO_2 equivalent production.

(5) Give definitions of key terms
These farms produce 402,500 chickens/year assuming the average chicken production per farm is the same as in Kentucky (from where reliable information is most easily accessible) (University of Kentucky, 2018).

(6) Outline key assumptions
The average production of chickens per farm, per year is the same in New Zealand as in Kentucky (University of Kentucky, 2018).

The past tense is only used in the last sentence to sum up why each assumption was made

The above assumptions were made to allow the use of outdated and international data where no recent data was available for New Zealand.

Discussion

The present tense is used throughout the Discussion. For example, the present tense is used to:

(1) Describe the Table and the Figures
The key assumptions are identical to the corresponding assumptions in Table 1.

(2) Outline issues around ethics and morality
The ethical acceptability of raising broiler chickens for slaughter is the subject of an ongoing debate.

(3) Describe the challenges
New Zealand's climate presents the greatest challenge to the viability of soybean farms.

Conclusions

The present tense is used throughout the Conclusions. For example, the present tense is used to:

(1) Refer to data that provide a summary of the research findings
Overall, 10x more input is received by the human consumer, and only 16.4kg of soybeans must be consumed for every 21 kg of chicken meat to receive an equivalent quantity of protein.

(2) Describe the challenges
New Zealand's temperate climate provides the greatest barrier to the success of soybean farms.

Active and passive voice

Both the active and passive voice are used in this engineering report. The writer chooses whether to use the active or passive voice depending on what is being said and where the focus is to be.

When the active voice is used, the subject of the sentence is the *doer* or *performer* of the action, and the object is the *receiver* of the action. The active voice in the following example from the Abstract is used because the writer wants the focus to be on the *performer* of the action (i.e., "This report":

> This report evaluates the suitability of soybean farms as an alternative source of protein production in New Zealand to broiler farms.

In contrast, the passive voice is used in the Abstract where there writer wants to focus to be on the *receiver* of the action (i.e., 10x more input energy):

> Overall, 10x more input energy is received by the human consumer …

The passive voice in the past tense is used where the experimental procedure is referred to because the focus is on the result of the *action* that has been completed, rather than on *who* carried it out:

> The information required was obtained through a literature search.

Aspect

The progressive aspect (e.g., It is starting) is not used at all in the report and the perfective aspect (e.g., It has started) is occassionally used when the writer wants to refer to an action which started in the past and is still of current relevance:

> Soybean farms have already proven successful in other countries, with 77.5 million acres being planted in the USA in 2009 (Ash, 2017).

> … all free range chickens have access to a range 1.5x the floor area of the barn as required for SPCA accreditation (PIANZ, 2018).

Annotation key

Tentative claims	Strong Claims	Transition signals	Specialised vocabulary

Reduced relative clauses

A further feature of engineering research reports is the use of reduced relative clauses. Use of such clauses helps make the writing concise. Reduced relative clauses are in the passive voice and should not be confused with the simple past tense as this example illustrates:

> The information required was obtained through a literature search. [passive]

The verb "required" in the above example is the non-finite –*ed* participle. If this clause had been written as a full relative clause, it would say:

> The information that was required was obtained through a literature search. [passive]

If this sentence had been written in the active voice, it would have placed unnecessary focus on the researcher carrying out the action:

> The information that the researcher required was obtained through a literature search. [active]

Modal verbs

Modal verbs are used for a number of reasons which include:

(1) Expressing uncertainty
As soybeans are soured from plants, the ethical issues associated with their consumption are reduced; genetic modification of soybean plants may present an ethical issue for some, however (Bawa & Anilakumar, 2013).

(2) Making a stronger claim
The use of plants rather than animals increases the likelihood that New Zealand consumers will overall be more morally satisfied.

Removing chickens from the energy equation would result in humans receiving 1% of the total energy input, rather than 0.1% currently.

(3) Expressing possibility

Additionally, soybeans have a similar nutritional composition to chicken (Johnson, White, & Galloway, 2008), so may serve as a more humane alternative.

Soybean plants, however, could still be used in a crop rotation from November to March in the North Island.

Developing a coherent argument

An important feature of a well-written research report is that it is coherent and well-structured. A variety of strategies can be used to ensure that the ideas are logically connected to one-another. One is to use "transition signals" such as "however" and "In this way":

> The lack of economic viability for most of the year makes it unlikely that soybean farms can completely replace broiler farms in New Zealand. However, North Island farmers could grow soybean crops during the summer season, rotating to other crops during colder seasons. In this way, soybean farms could partially replace broiler farms in New Zealand.

Another feature is to use a pronoun such as "it", "this", or "these". If using a pronoun, however, check that the meaning is clear as in the following example where the pronoun clearly represents. Otherwise, if the meaning of the pronoun is not clear, it is preferable to repeat the noun or noun phrase, or use a synonym or a noun phrase, as shown in this example where the phrase "this range" points back to the previous paragraph in which "an optimum temperature range" was given:

> New Zealand's climate presents the greatest challenge to the viability of soybean farms. Most varieties of soybean plants have an optimum temperature range of 20 – 25°C (Martin, 1988).
>
> The only five-month period (average time to maturity of soybean crops) (Kowalski, 2018) within which New Zealand experiences mean maximum temperatures in this range is from November to March (with minimum temperatures fluctuating between 9 - 14°C) (NIWA,

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