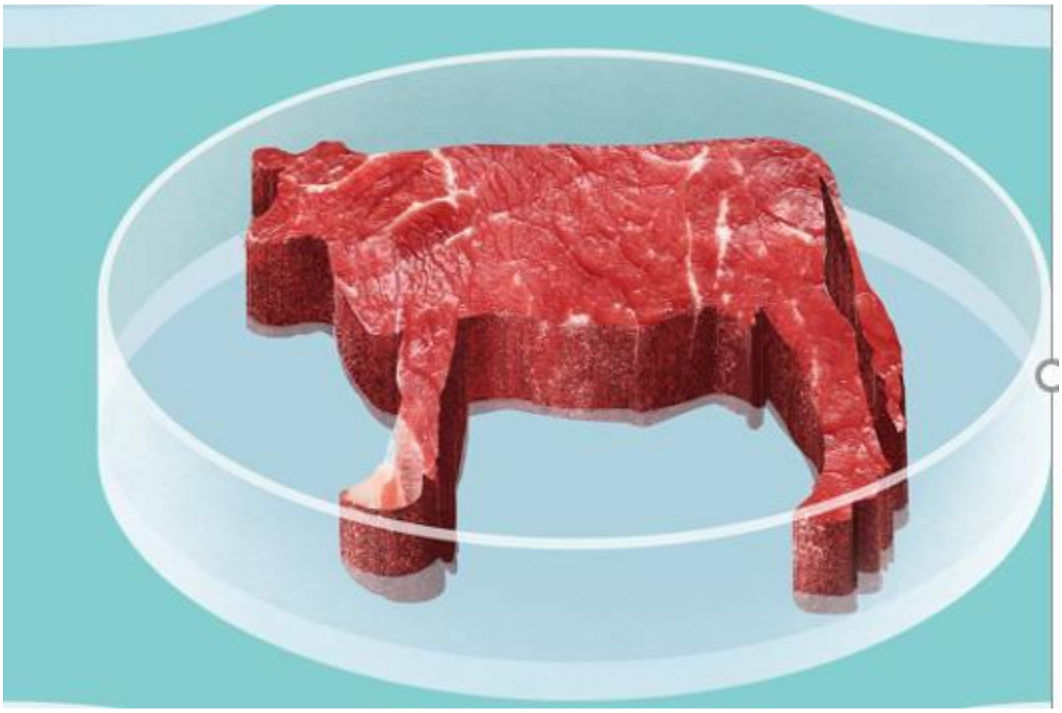

Meat without the moo

A lifecycle assessment comparison of

Cultured Meat and NZ Beef

Kellogg Rural Leadership

Programme

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I wish to thank the Kellogg Programme Investing Partners for their continued support:

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Executive Summary

Global food systems are experiencing unprecedented changes in the way food is produced, distributed and consumed. Food systems are highly dependent on fossil fuels, emit large quantities of greenhouse gases (GHGs) and significantly contribute to environmental problems (FAO, 2006). Agricultural farming systems particularly in New Zealand are under increasing pressure given the growing awareness of agriculture's contribution to GHGs and deteriorating water quality.

New Zealand's social, environmental and economic wellbeing is linked with our ability to supply the rest of the world with protein. Animal-based protein production alone accounted for over 60% of our total 2016/17 primary export revenue (Sutton et al., 2018). A temperate climate combined with advanced production systems make the NZ dairy, sheep and beef industries among the most competitive in the world. Consequently, increasing world demand for food will be a significant factor in New Zealand's economic growth and prosperity over the next half century (Hilborn and Tellier, 2012).

Consumer concerns around the impacts of agriculture on the climate, animal welfare and water quality are increasingly influencing their purchasing decisions as they look to reduce their environmental impact including their contribution to climate change (Goldberg, 2008). This demand has led scientists to develop alternatives to animal protein from farmed animals. These alternatives have been coined "Alternative Proteins".

This report outlines two types of alternative proteins, these being plant based proteins and cultured meat. Plant based proteins are currently in market, whilst cultured meat is still under development. Cultured meat has the greatest potential to displace traditional farming as if successful it could address the environmental issues created from large scale intensive farming, by growing meat in a laboratory setting. However to be viable and to successfully compete against real meat, cultured meat needs to overcome a number of challenges. These include issues around public perception, cost, the ability to scale and the ability to deliver on environmental benefits.

Significant financial investment is being made into the research and development of alternative proteins and current estimates predict cultured meat will be in market within the next 5 to 10 years.

A Life Cycle Assessment (LCA) was carried out as part of this report comparing the environmental impacts of cultured meat in comparison to NZ Beef. The results showed that production of 100g of cultured meat requires 0.021m^3 water, 0.022m^2 land and emits 0.207 kg CO_2-eq Greenhouse Gas (GHG) emissions. In comparison to New Zealand Beef, Cultured Meat involves approximately 91% lower GHG emissions, 99% lower land use and 99% lower water use. Despite high uncertainty, it is concluded that the overall environmental impacts of cultured meat production are substantially lower than those of conventionally produced NZ beef.

Cultured meat is still in the development phase, so it is too soon to know whether cultured meat will be a marketable product, or whether the estimated environmental impacts presented here will be able to be achieved.

In order to remain profitable and sustainable in to the future, NZ agriculture needs to work on being the best that we can be in terms of our systems and practices. We need to work collaboratively both as a country and as an industry to market our products with a strong natural, grass-fed message. We need to target our products to the markets willing to pay the highest prices for these and continually look for opportunities to add further value to these products. Furthermore we should look for opportunities to diversify our farming and meat processing operations. Lastly we need to continually invest in NZ agriculture, market research and our communities in order to future proof our industry.

Given the shortfall in the current food supply predictions to feed the worlds growing population by 2050, it is anticipated that there will be room in the market for both alternative proteins and traditionally farmed meat. Nevertheless there is an increasing awareness of the impact of agriculture on the environment, on animals and on human health, which NZ Agriculture needs to stay abreast of.

1. Introduction

The world is on the precipice of a technological revolution that will impact many aspects of our lives. This revolution in terms of its scale, scope, and complexity, will be unlike anything humankind has experienced before.

The First Industrial Revolution used water and steam power to mechanize production. The Second used electricity to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. This Fourth revolution is characterised by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

There are three reasons distinguishing the Fourth industrial revolution from that of the Third: velocity, scope, and systems impact. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear rate. Moreover, it is disrupting almost every industry in every country. And the breadth and depth of these changes signal the transformation of entire systems of production, management, and governance (Schwab, 2016).

In parallel to this, is the revolution of Agriculture. From a hunting-and-gathering society to stationary farming, this developed further during the 18th century, when agriculture shifted to favour new patterns of crop rotation and livestock utilisation. This paved the way for improved crop yields, a greater diversity of wheat and vegetables and the ability to support increased livestock numbers. These changes impacted society as the population became better nourished and healthier. However, by increasing the amount of land farmed, wealthy lords in England were able to push out small-scale farmers, causing a migration of workers looking for wage labour in cities. These workers would provide the labour for new industries during the Industrial Revolution, and led to the migration of rural dwellers to urban centres.

Feeding the people of the future

Fast forward to 2018, and agriculture is on the cusp of change once more. The world population has significantly benefited from the technological advances made in agriculture to date. However in 2006 the Food and Agricultural Organisation (FAO, 2006) released a report estimating that by 2050, the world population will soar to 9 Billion people. In order to support a population of this magnitude, the FAO estimates that meat production will need to increase by approximately 50-73% to maintain per person demand for the growing population (FAO, 2009). PWC (2017) estimates by 2050, six out of the seven largest economies will be from developing markets; thus they will have more income with which to purchase animal protein. History has shown that with increasing wealth comes increased demand for animal protein (FAO, 2017). The current estimates for global population and affluence growth suggest an increasing strain on our natural resources if current methods are used to meet future demands.

Environmental constraints

Atmospheric concentrations of greenhouse gases (GHG) have steadily increased throughout the twentieth century, and this is thought to be contributing to an increase in the surface temperature of the earth and related changes in global climate (IPCC, 2006). Livestock, particularly ruminants are considered major contributors to global greenhouse gas emissions, and environmental degradation. Currently livestock raised for meat use 30% of global ice-free terrestrial land and 8% of global freshwater, while producing 18% of global GHG emissions (FAO, 2006). Livestock production is also one of the main drivers of deforestation, and degradation of wildlife habitats and it contributes to the eutrophication of waterways. Globally, 34% of the GHG emissions related to livestock production are due to deforestation, 25% are methane emissions from enteric fermentation of ruminants and 31% of the emissions are related to manure management (FAO, 2006).

The Agtech movement is now maturing rapidly with investors funnelling more and more investment into new start-ups looking to disrupt traditional agriculture (Meagher, 2018). KPMG predicts that a dominant mega-trend in global agriculture for the foreseeable future will be sustainability; the need to produce enough food for a rapidly growing world population over the next half century and beyond, at the same time as reducing environmental impacts from pesticide use and protecting water quality. They maintain that Agtech will play a key role in meeting that challenge.

Not only is the population, technology and environmental constraints changing, so too are the preferences and demands of consumers.

Consumers are increasingly becoming more complex

During this fourth Industrial revolution, agriculture has been one of the last sectors to experience significant disruption from new technologies. Historically, food was used to solely provide people and their families with sustenance and nutrition. Today, particularly in premium market segments, this can no longer be taken for granted. People now purchase food products for a wide range of reasons; including enhancing health, demonstrating status, following fashion, highlighting political agendas, for moral reasons and creating social interactions (Proudfoot, 2018). This shift is particularly evident amongst Millennials (people born between 1981 and 2000). Coined “mindful eating”, this demographic are particularly concerned around where their food comes from and its health attributes. (Beef + Lamb New Zealand, 2018a). With 27% of the world’s population identifying as millennials (Beef + Lamb New Zealand, 2018a), these concerns need to be taken seriously.

There is also a growing disconnect between consumers and the land and where food comes from, as greater proportions of the world’s population live in urban areas. In 2014, 54% of the worlds’ population lived in urban areas and projections estimate by 2050 this will increase to 66% (UN, 2014). In comparison, in New Zealand greater than 80% of the population now lives in urban areas (Statistics NZ, 2001). As a result there is an increasing lack of understanding of common farm practices, and a growing scrutiny about some of these practices.

2. Aims and Objectives

The objectives and purpose of this report are to provide the reader with an overview of Alternative Proteins, and then to assess whether they are more environmentally sustainable in comparison to NZ agriculture by comparing the life cycle analyses of a typical NZ beef farm in comparison to that of cultured meat.

3. Proteins

Proteins are one of three key macronutrients, along with carbohydrates and fat needed in human diets. These macronutrients are vital for a healthy diet, and are responsible for growth, maintenance and repair of body tissue, providing energy and forming antibodies and enzymes. Unlike the other two macronutrients, the body does not store protein, so it must therefore be consumed regularly.
There are 20 amino acids used by our bodies as building blocks for proteins, 9 of which are referred to as essential because our bodies cannot make them, so they must come from our diet.

Proteins are found in many food sources, however some plant proteins lack one or more of these essential amino acids and are therefore termed incomplete proteins. Generally, proteins derived from animal foods (meats, fish, poultry, milk and eggs) are complete. Many proteins derived from plant foods (grains, legumes, seeds and vegetables are close to complete including chickpeas, black beans, cashews, potatoes, quinoa and soy protein (although soy protein has been genetically modified to achieve this) (Sutton et al., 2018), to name a few.

While animal proteins continue to appeal to traditional consumer preferences, consumers are now more conscious of their overall health and wellbeing, and how their food is produced in terms of the environmental impact and the welfare of the animals the food is produced from. This demand has led scientists to develop alternatives to animal protein from farmed animals. These alternatives have been coined "Alternative Proteins". Research into alternative proteins is growing, and there are a number of areas that this subject covers. For the purposes of this report, I will outline what an alternative protein is, followed by an outline of the two main types of alternative proteins – Plant based proteins and Cellular meat.

4. Plant based proteins

There are numerous and varied sources of plant protein; from the minimally processed chickpeas, and quinoa type plant proteins to moderately processed e.g. Tofu and nut milks (e.g. almond milk) to the highly engineered meat substitutes like the Impossible burger.

Plant based alternative proteins have been developed in various ways – some replace flesh-based proteins e.g. Tofu, whilst others have been developed to replicate the texture of animal proteins with the use of mycoproteins, or wheat gluten or soy protein bases. At the far end of this scale is the more recently marketed products that are engineered to closely replicate the meat eating experience, with the impossible burger having been developed to "bleed" like meat.

Plant proteins are not a new concept, with the likes of Tofu, a coagulated soybean milk product high in protein having been part of Chinese diets for over 2,000 years. In the Western world, meat substitutes have been available to consumers for at least 30 years, many of which have been made to look like meat. These include brands such as Quorn and Linda McCartney's (named after the late wife of Beatle Paul McCartney). These products use plant based proteins such as mycoproteins (derived from *Fusarium venenatum* fungus) or soya and wheat proteins as a substitute to animal protein, and have been formulated into ready-to-cook forms, including forms resembling minced meat, sliced meat, meatballs, hot dogs, and burgers.

Other examples of plant based proteins include substitute products for example "dairy" including soy, almond, coconut and rice milk, vegan cheese, coconut yoghurts and ice creams; and vegan eggs to name a few. These products will not be detailed further as part of this report. All of these products have traditionally been consumed by vegetarians, vegans and people with food intolerances.

Within the last ten years new entrants have appeared in the market, attempting to create products that replicate the meat eating experience as closely as possible. Beyond Meat and Impossible foods are two examples. Beyond Meat offers a pea protein-based patty designed to look, cook and taste like fresh ground beef. The Impossible burger patties are made from plant based proteins, and use a genetically engineered yeast process to make heme that replicates a meat like blood in its burgers (Heme is an iron-containing molecule in blood that carries oxygen and is claimed by Impossible Foods to be a key part of what makes meat taste the way it does) (Shapiro, 2018). The genetically modified (GM) yeast is removed prior to the completion of the final product, so the product is technically GM free, but uses GM in the manufacturing process. These products are currently available in supermarkets (next to animal protein in the chillers) and restaurants now.

In terms of plant proteins and whether they are a threat to NZ agriculture, they should be seen as an opportunity to diversify. With growing demand for plant protein, there is a potential for animal protein to reduce, so NZ farm animal numbers may reduce, however the plant component of plant protein still needs to be grown, and therein lies an opportunity for NZ farmers. By adopting land use change there is opportunity for farmers in NZ to set aside land to grow crops to fulfil supply for plant proteins, reducing animal numbers, and minimising the risk of disruption. In addition, the environmental impacts of growing crops will be lower than those of farming animals, allowing NZ farmers to continue to operate under growing environmental regulatory pressure.

Currently NZ horticulture produces $8 billion of value from just 140,000 ha (Sutton et al., 2018). Whilst not all agricultural land in NZ is suitable for cropping, Sutton et al., (2018) estimates that there is more than 1,737,000 ha of land that could grow plant protein crops, based on criteria including appropriate slope, ease of access and climate.

Given the opportunity for NZ farmers to potentially diversify their land use in order for them to grow plant proteins and therefore operate in this market, this report will focus solely on cultured meat and whether it will be a potential competitor for NZ agriculture.

5. Cultured Meat

In parallel to the development occurring in the plant based protein space has been the development of an animal derived alternative protein referred to as cultured meat. Whilst not suitable for vegetarians or vegans, as this meat is derived from animals, it offers a solution to the incomplete protein nature and the taste and textural differences experienced with plant proteins. Furthermore it also addresses the environmental issues created from large scale intensive farming, by growing meat in a laboratory setting.

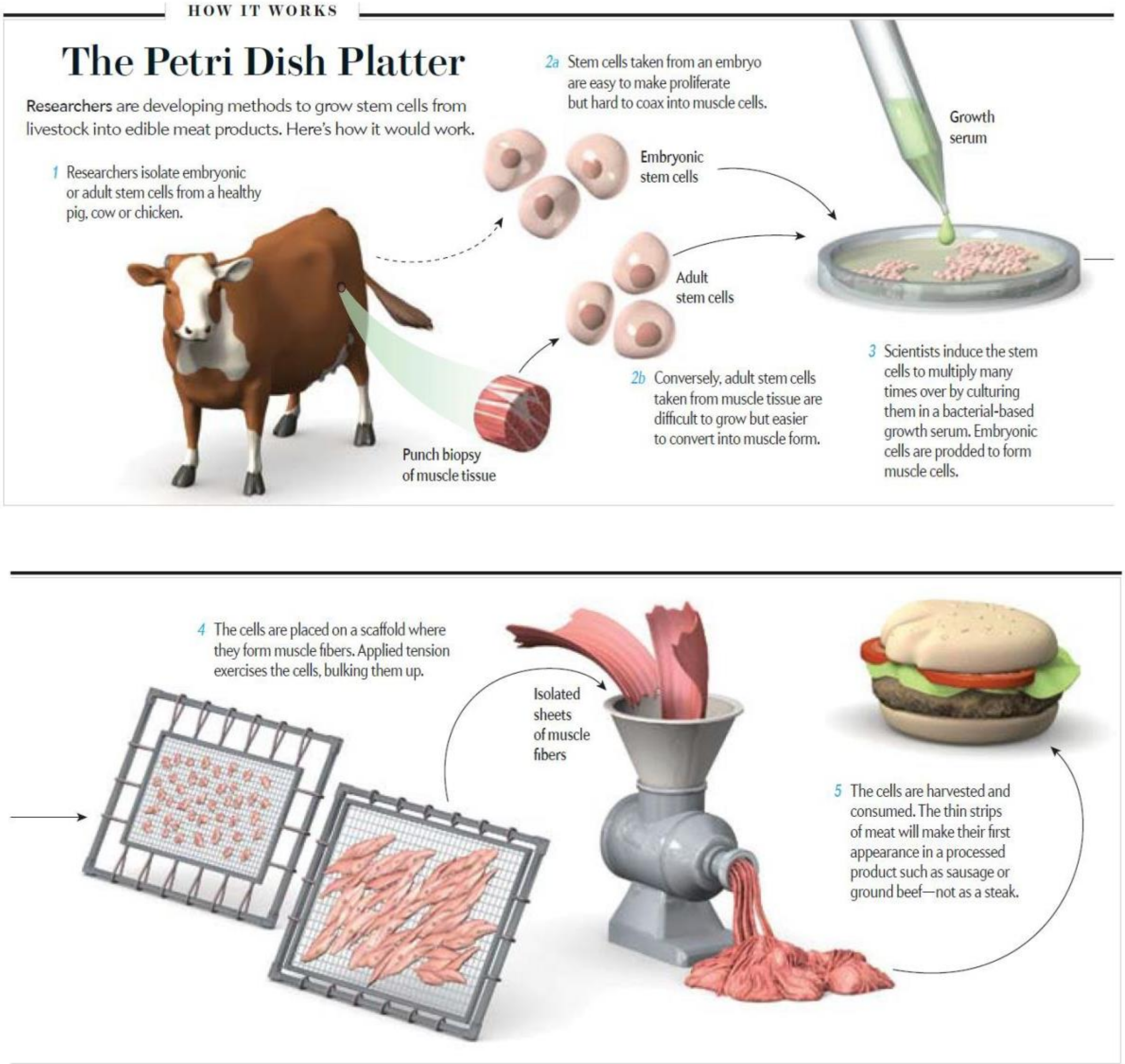
The term cultured meat (often referred to as lab grown meat, or clean meat) is a term used to describe growing animal tissue in vitro, instead of growing a whole animal as has traditionally been done in a farming setting (Tuomisto, 2011). This technology is currently in the research stage, only small quantities of cultured meat have been produced in laboratories to date, and at this stage of development, only a minced meat product can be made.

How is cultured meat manufactured?

In order to culture meat, scientists collect a biopsy sample from an animal's tissue, and isolate growing cells from this sample –refer Figure 1. These isolated cells are then affixed to a scaffold in order to anchor them in place while they proliferate. They are placed in a nutrient rich medium to feed the cells and allow them to further divide and grow in number.

The nutrient solution contains salts, pH buffers, and the building blocks of cellular structures like proteins and fats. It also contains molecules called growth factors, which direct the cells to behave in certain ways. For example these factors direct cells to become muscle, fat, or blood cells. Traditionally these factors were obtained from bovine foetal serum (which requires the slaughter of a pregnant cow). The harvest of foetal bovine serum raises ethical concerns particularly when the product aims to reduce the welfare implications on animals and the ultimate aim is to produce an animal free protein. However serum has largely been phased out. Hundreds of serum free formulations exist, Benjaminson et al., (2002) succeeded in using a serum free medium made from maitake mushroom extract that achieved higher rates of growth than foetal bovine serum. However, many serum free formulations are too costly for commercial viable cultured meat production (Specht & Lagally, 2017).

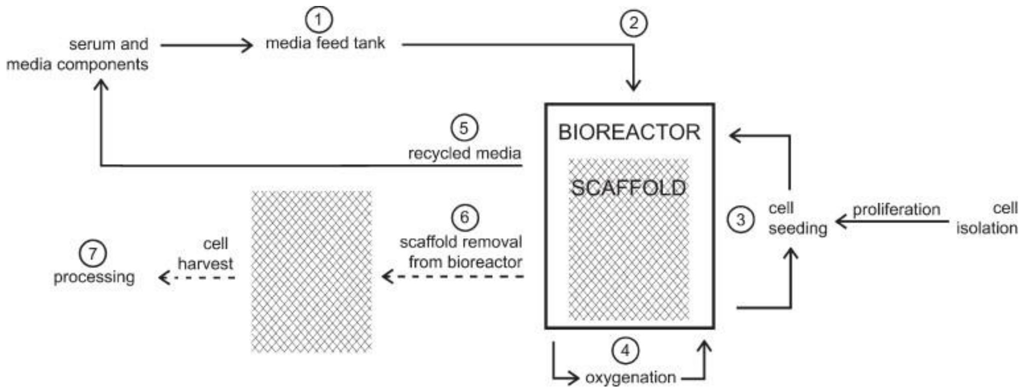
Figure 1. An illustration summarising the process to create cultured meat from animal cells



Sourced from: Bartholet, 2015

This scaffold is then placed inside a bioreactor (a steel drum in which cell culture takes place) - refer Figure 2. with electrical stimulation to exercise the cells and keep them warm. The meat is harvested and any further processing is performed including adding fat or other flavours. Currently only ground meat is able to be produced from this technique, as the cells in the centre of thicker muscles become deprived of nutrients in the absence of blood vessels to transport nutrients evenly (Shapiro, 2018).

Figure 2. A diagram showing the bioreactor process used to culture cells for cultured meat



Sourced from: Datar and Betti, 2010

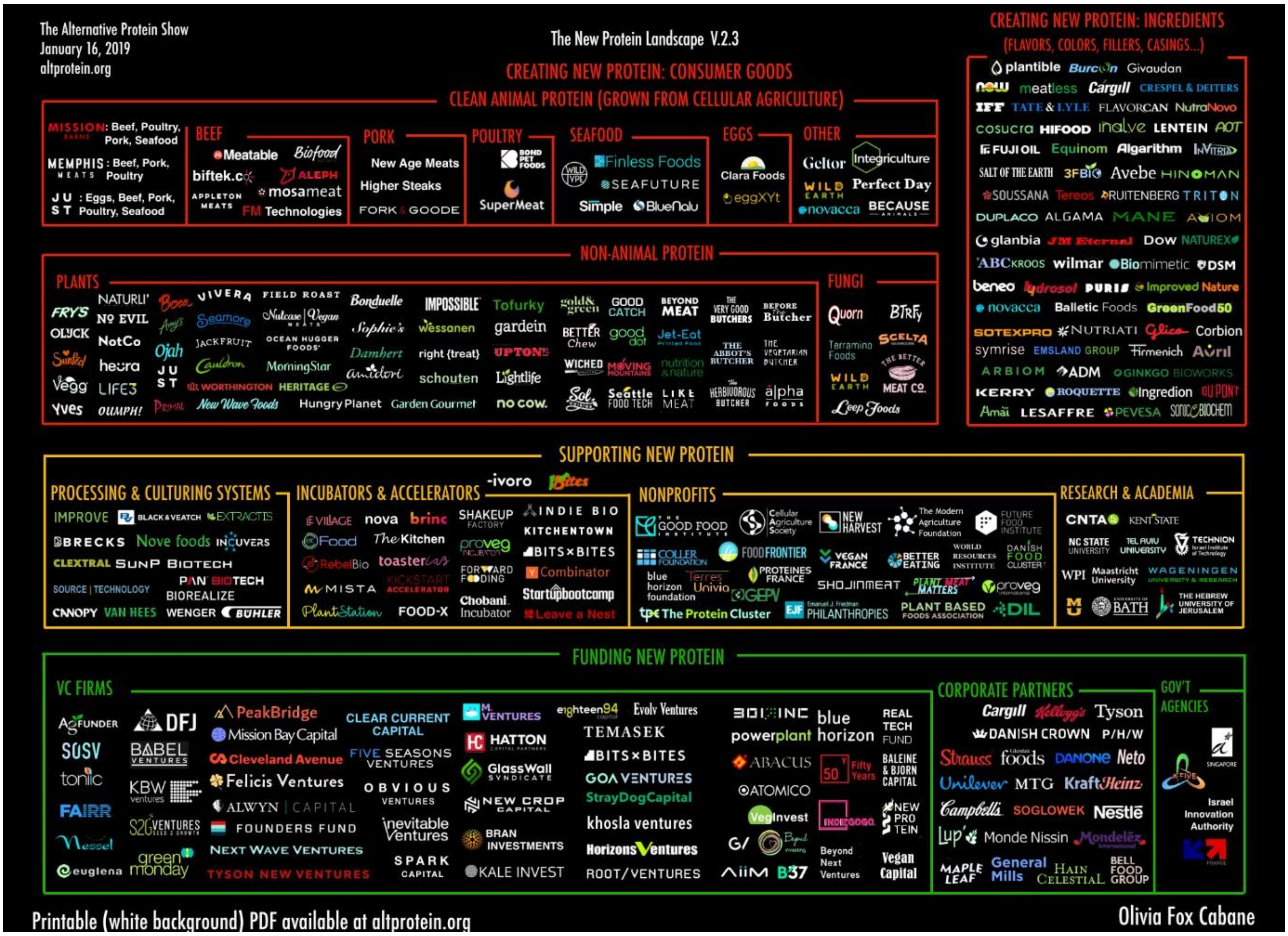
Other examples of cellular agriculture under development (but not covered in this paper include chicken, scampi, leather, and foie gras (fatty duck liver), amongst others.

Where is cellular meat manufactured, and how much does it cost?

There are many laboratories working on cultured meat technology around the world - refer Figure 3, however to date no products have been launched in the market. In 2013, Mark Post from Maastricht University in the Netherlands in a highly publicised London event, created a cultured meat hamburger funded by Google co-founder Sergey Brin. The burger cost approximately USD $350,000 to create and it took three months to produce a single cultured meat patty consisting of 10,000 cultured meat strips totalling 15 billion cells (Bartholet, 2015). Three years after Post's event, another competitor in the cultured meat arena Memphis Meats, co-funded by cardiologist Uma Valeti, held a private tasting event for a cultured meat meatball. This meatball was developed for a significantly lower price of USD$1,200 (Shapiro, 2018). Mark Post optimistically estimates that large scale production of cultured meat could lower the price down to USD$20 per kg, with the potential for advancing technology to reduce the costs even further (Bartholet, 2015). In 2017 Valeti was quoted as saying "we are confident we will be able to produce meat at a price that is cost-competitive with (and eventually more affordable than) conventionally produced meat", and both he and Mark Post predict that cultured meat will be in market within 20 years (Shapiro, 2018), however a Beef + Lamb Report (2018a) estimates that there will be entrants into the cultured meat market within the next 5 to 10 years.

The publicity events held by both Post and Valeti have demonstrated that these products can be made in a laboratory, and are only years away from market. However, in order to be successful, there are a number of hurdles that cellular meat needs to overcome first. These hurdles will be outlined in the next section.

Figure 3. A graphic showing the company logos of organisations involved with alternative proteins



Sourced from: altprotein.org

6. Challenges for Cultured Meat

To become viable products in the market and to successfully compete against real meat, alternative proteins need to overcome a number of challenges. These include issues around public perception, cost, the ability to scale and the ability to deliver on environmental benefits. The perception of cultured meat as fake meat, scary or disgusting is something that will need to be overcome. Consumers have reservations about eating "fake meat" as this doesn't sound appealing. There is also a psychological barrier for many consumers towards eating lab grown meat, surrounded by connotations of being unnatural and man-made. However it could be argued that this isn't as prohibitive as first thought, given the recent marketing by Air NZ of its collaboration with Impossible Foods, serving Impossible Burgers on their flights between NZ and San Francisco. Air NZ was able to create interest in this launch by developing a marketing campaign glamourising the burger, and selectively offering it to only their premium customers. This therefore created the image that wealthy, environmentally conscious consumers eat alternative proteins and these products are high tech and leading edge. However this man-made element is taken one step further when comparing real meat to that of cultured meat, as the process is all conducted in vitro and traditional farming which is still present for growing the plant component of plant proteins,(as is the case for Impossible Burgers), is absent for cultured meat.

Alternative proteins are more expensive than animal protein. As outlined in an earlier section in this report, cost remains as a largely prohibitive factor that will need to be overcome particularly for cultured meat. In order to compete with real meat, it will need to compete on price or become cheaper. Companies working in this area are actively seeking ways to reduce the cost of production, and are achieving significant reductions in cost year on year (Beef + Lamb New Zealand, 2018a), as demonstrated by the Maastricht University/Memphis Meat example outlined earlier. Costs are also high for the foetal bovine serum required to make cultured meat, not to mention ethical issues around the culling of pregnant cows to obtain the serum, although this too can be solved if costs can be lowered for alternative methods.

The scalability of cultured meat is crucial to its success and has yet to be mastered. Production scale challenges in order to achieve mass production and distribution, including operational and product development hurdles as well as availability of ingredients will need to be overcome. Much of the technology being used at the moment was invented for medical not food purposes, limiting in terms of both size and cost what is currently possible. Industrial bioreactors will need to be developed in order to culture meat on a large scale. Scientist's knowledge as to how to tissue engineer cultured meat and the technology to do this at scale is still developing, and will require significant financial investment to master these concepts.

7. Opportunities for Cultured Meat

Whilst there are still significant hurdles for cultured meat to overcome, there are significant benefits being marketed for this technology. Culturing animal meat in vitro has the potential to overcome many of the limitations of traditional animal farming. These include reduced food contamination, increased animal welfare, standard meat flavour and texture, health benefits and reduced environment impacts.

Although Mark Post's team took USD$350,000 and 3 months to make one burger, cultured meat could eventually be more cost-effective than traditional meat farming practices. In vitro growth takes several weeks before meat can be harvested, rather than weeks or months for chickens or years for pigs or cows. Furthermore, from one sample from a cow, cultured meat can currently produce 800 million strands of muscle tissue (enough to make 80,000 quarter pounder burger patties) (Mosa Meat, 2018). Cultured meat also has the ability to be stored in the facility where it is grown, reducing the need for land, labor and feed to raise animals. Further, it could create a new, profitable industry. However, more research is needed to develop the technology and make it widely available.

If developing cultured meat on a large scale were successful, farming and agriculture as we know it would undergo significant changes. Researchers hypothesise that cultured meat could lead to monumental changes in meat production, perhaps replacing intensive farming or increasing demand for small-scale farming. Cultured meat aims to use considerably fewer animals than conventional agriculture, reducing the animal welfare concerns related to traditional agriculture.

The livestock sector is the fastest growing subsector of agriculture and employs 1.3 billion people. Although cultured meat would create a new profitable industry of its own, it could greatly affect traditional livestock farming. Global meat production has more than doubled since 1970, and researchers estimate cultured meat could reduce both greenhouse gas emissions associated with meat production and deforestation of grazing land. Furthermore, cultured meat could decrease soil erosion and relieve pressure on the world water supply.

Cultured meat can be engineered to have an impact on specific health and nutrition outcomes by altering the profile of essential amino acids and fat in addition to adding vitamins, minerals and bioactive compounds that match or exceed the amount in natural meat. For example, cultured meat could be grown to contain more protein and polyunsaturated fatty acids than traditional meat, as well as decreased or eliminated saturated fat, potentially reducing the risk of chronic diseases. In addition, as cultured meat is developed from animals, unlike plant proteins, the flavour and texture of cultured meat should better emulate the flavour of real meat.

Controlled conditions used in growing cultured meat could improve food safety by minimizing animal-borne diseases and pathogens, such as *Salmonella*, *Campylobacter* and *E. coli*. In vitro meat also could reduce disease outbreaks associated with livestock farming that humans can contract, including avian and swine flus and bovine spongiform encephalopathy, or mad cow disease.

Scientists also hope that growing cultured meat could reduce the need for pesticides, fungicides, heavy metals, aflatoxins, melamine, anabolic agents and antibiotics used for some large-scale traditional meat production.

As mentioned in the section above, significant financial investment is required to develop the technology required to take cultured meat to market at scale. Events such as the publicity stints by both Mark Post and Uma Valeti have created a lot of hype around cultured meat, which has paid dividends in terms of attracting high profile wealthy investors. In the case of Memphis Meats, they have financial backing from some of the world's wealthiest people including Richard Branson, and Bill Gates, and investment from two of the largest meat processing companies; Cargill and Tyson's (Memphis Meat, 2018). The fact that large (real) meat companies are investing into organisations such as Memphis Meats suggests that they see cultured meat as a potential threat to their businesses – further supporting the argument that cultured meat has the potential to disrupt the agricultural industry.

Ultimately consumer perception will determine the commercial viability of cultured meat. The alternative protein category is sure to grow over the next decade as global protein demand expands. Euromonitor International projects sales of meat substitutes to rise steadily to $863 million in 2021, representing roughly 17 percent growth compared to 2017 estimates (Amen, 2017).

Market forecasts predict that cultured meat will initially appeal to consumers who are concerned with the environmental and ethical aspects of current livestock production (Amen, 2017). Current product positioning among cultured meat marketing efforts revolve around making comparisons to traditional production systems in terms of environmental attributes including comparisons of land and water utilisation, greenhouse gas emissions, input conversions and nutritional attributes (Mosa meat, 2018). In time, the target audience could shift from just these environmentally conscious consumers and appeal to a broader base of consumers, however this will be reliant on the ability of cultured meat companies being able to compete on price with traditionally farmed meat.

These environmental benefits that are marketed by cultured meat organisations will be analysed later in this report using a Lifecycle assessment to compare whether cultured meat really is more sustainable than NZ Beef. But first we need to understand Agriculture, and then specifically New Zealand farming, and the current challenges and opportunities for our agricultural sector.

8. Global context

Although economically not a major global player, the livestock sector is socially and politically very significant. It accounts for 40 percent of agricultural gross domestic product (GDP). It employs 1.3 billion people and creates livelihoods for one billion of the world's poor. Livestock products provide one-third of humanity's protein intake, and are a contributing cause of obesity and a potential remedy for undernourishment (FAO, 2011).

9. The NZ Agricultural Context

New Zealand's social, environmental and economic wellbeing is linked with our ability to supply the rest of the world with protein. Animal-based protein production alone accounted for over 60% of our total 2016/17 primary export revenue (Sutton et al., 2018). A temperate climate combined with advanced production systems make the NZ dairy, sheep and beef industries among the most competitive in the world. Consequently, increasing world demand for food will be a significant factor in New Zealand's economic growth and prosperity over the next half century (Hilborn and Tellier, 2012).

Fourteen million hectares of land is farmed in New Zealand, of which 9.3 million hectares (ha) is utilised for sheep and beef farming, 2.4 million ha for dairying, 284,000 ha for cropping, 287,000 ha for deer farming, 11,000 ha for pig farming, 3,000 ha for poultry and 2.0 million for "other purposes" (including forestry) (Beef + Lamb New Zealand, 2018b).

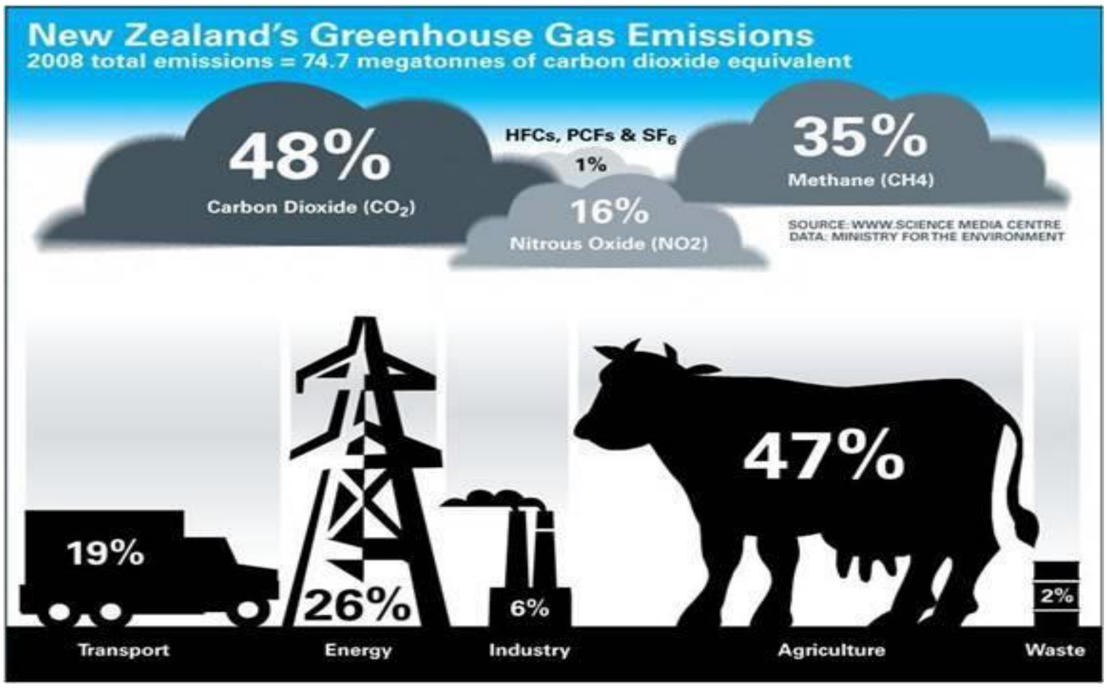
Gross Domestic Product (GDP) from NZ Agriculture reached an all-time high of NZD$3.3 billion in the second quarter of 2018 (Trading Economics, 2018b). Despite reaching a GDP all-time high, in terms of employment only 6.6% of New Zealand's population are employed by agriculture (Trading Economics, 2018a) and furthermore, only 14% of New Zealand's population reside in rural areas. This demographic split has a real impact on the outcome of national decisions particularly when 87% of voters live in towns but greater than 60% of the nation's bills are paid for by farmers (Bruce, 2014). This split was particularly evident in the last election, and will be outlined further in the next section, as one of the challenges facing NZ agriculture.

10. Challenges for NZ Agriculture

A major hurdle for NZ agriculture's potential future growth is the increasing concerns around the impact of agriculture on New Zealand's environment. Environmental concerns around the effect of intensive agriculture on NZs water quality and Greenhouse gas emissions became a political lever in the 2017 Governmental elections. In her political campaign, now Prime Minister, Jacinda Ardern described taking action on climate change as her "generation's nuclear free moment". (Small, 2017).

Historically the NZ government initiated an emissions trading scheme (ETS), which has put a charge on GHG emissions from fossil fuel and electricity use (Ledgard et al., 2012). Agricultural-related emissions (animal production and nitrogen fertilisers) carry reporting obligations only, and were deferred indefinitely in 2012 from inclusion in the ETS. The government's rationale for deferring unit obligations for agriculture in 2009 and 2012 included a lack of cost-effective mitigation options and competitiveness considerations. GHG are a major concern for New Zealand, and our freedom to operate. New Zealand agriculture accounts for 47% of GHG emissions and of this, Methane (CH_4) accounts for 35% (mostly from ruminal fermentation), and Nitrous oxide (N_2O) accounts for 16% of GHG emissions mostly from urinary N, exacerbated by excessive application of nitrogenous fertiliser (Pinares-Patiño et al., 2009) - refer Figure 4.

Figure 4. An infographic showing the proportion of greenhouse gas emissions by sector and by gas emitted in New Zealand



Sourced from: Science Media Centre (2018)

Furthermore water quality has also been a contentious issue in NZ with many of NZ's waterways having increased in their nitrogen and phosphorus levels. In rural environments, pastoral farming, and more specifically; agricultural fertilisers, stock manure and urine are the major non-point sources of this nitrogen and phosphorus enrichment.

11. Opportunities for NZ Agriculture

For NZ agriculture to remain strong in the foreseeable future there are 5 key opportunities that should be exploited.

These are as follows:

1. Do what we do better
2. Collaboratively tell our story
3. Diversify
4. Target Markets
5. Invest

Each of these 5 key opportunities will be elaborated on in more detail below, with particular emphasis on how NZ can capitalise on these opportunities.

Doing what we do better

In order to remain competitive, NZ agriculture needs to continue to do what we do, but better. By better, I mean there needs to be greater transparency and traceability around our farm management practices, animal movement information, animal welfare standards and practices, and environmental footprints. The development of farm environment plans has been a good step in the right direction to start this process.

Damage to the NZ Inc. brand by poor practice is now more destructive than ever before with social media just a click of a button away. In addition, with consumers being more conscious of animal welfare and the effect of agriculture on the environment – their purchasing decisions will be determined by the information provided to them on these practices. Furthermore, with these checks and balances in place NZ agriculture will be more secure against the likes of biosecurity threats. The *Mycoplasma bovis* outbreak has demonstrated the holes in NZs animal movement system, and further emphasises the need for tighter processes and regulations in this area. In order to set up these processes, farmers need to be incentivised for good practice, and there needs to be clear penalties for not conforming.

In addition there are opportunities to create further efficiencies on farm, such as addressing the issue of bobby calves. By utilising bobby calves within the sheep and beef sector, environmental efficiencies can be gained, as well as avoiding an animal welfare issue in the dairy industry. Other work around introducing wagyu and sexed semen into the dairy industry has gone some way to resolving the bobby calf issue. By creating clearer transparency around NZ agriculture, NZ in turn will have a stronger story to tell.

Collaboratively tell our story
We need to tell our story more collaboratively. NZ as a whole needs to buy in to the NZ agricultural story. With 87% of New Zealanders living in urban areas, with little or no contact with agriculture, a distinct divide is occurring. This has been labelled the rural-urban divide and needs to be addressed. Without urban NZ on the same team, there is potential reputational damage being done to the NZ Inc. brand from media capitalising on this disconnect.
There is an opportunity to take urban NZ on the journey, and have 4.8 million advocates for NZ agriculture, rather than just the 14% that live in rural areas. In order to do this we need to show greater transparency around our farming practices (as outlined above), acknowledge failings in the past, and promote the importance of buying local and the benefits from this. If we cannot convince our own compatriots of the benefits of buying our products how can we expect to convince others globally? More work needs to be done to engage urban NZ to build a brand that all New Zealanders are proud of.

Furthermore, there is opportunity for collaboration by processors, exporters and industry bodies, with marketing budgets pooled to jointly promote New Zealand beef or New Zealand lamb to our overseas markets. As a small country NZ needs to maximise collaboration in our industry to get maximum value for our money and ultimately our farmers which in turn supports NZs economy.

We also need to take the opportunity to tell our story. NZ agriculture has a great story to be told, we need to emphasise in our marketing and messaging particularly in our overseas markets that NZ red meat is grass-fed, free range, home-grown, natural and GM, hormone and antibiotic free. Sales of American beef marketed with a production claim (naturally raised, organic, grass-fed, etc.) have grown dramatically over the past 10-15 years (Amen, 2017).

We need to sell our biodiversity story in terms of the fact that most sheep and beef farms in NZ have either forestry or native bush on their land, and educate consumers around NZ farming systems and how different they are to US or other countries farming systems. These are all claims that allow us to compete in a market with alternative proteins. A number of individual groups around NZ have successfully marketed their products in this way, including Omega Lamb, Taupo Beef and Lamb and Coastal Spring Lamb. A premium, well-presented brand, may generate more revenue per kilogram (Norman, 2016).

Target Markets
There is opportunity for NZ agriculture to specifically target our meat cuts to the highest paying customers. This is particularly relevant for items such as offal that the Chinese for example are willing to pay more for than other markets. We need to understand the markets we sell into better, and tailor our cuts to these markets. In the past NZ has had a "quantity" type mind-set based on our products fitting a commodity market, which needs to shift to a producing "quality" mind-set. This will set NZ in good stead if clean meat becomes commoditised in future, because NZ meat will become a high value niche product. People often say "New Zealand produces enough food for 40 million people. We need to sell to the

world's wealthiest 40 million people." (Norman, 2016). This is an important message, and yes we should be targeting these people, however in order to do this we need to have the supporting transparency around our production methods, and a strong and compelling story behind our demands for the premium price we will be expecting for this premium product. Adding value to our products is another way to target particular markets. An example of this could be from adding health benefits e.g. as Omega Lamb has done around their Omega 3 product. In addition, with growing consumer demands for natural, antibiotic free agriculture, there could also potentially be a growing market for producing more organic products, which should be explored further.

Diversify
NZ has the opportunity to join the alternative protein movement. There is scope for some NZ farmers to grow crops suitable for alternative proteins on their land as opposed to animal protein. NZ farmers should see themselves as protein growers, and therefore utilise the appropriate land for this purpose if they are able. The added advantages of this are the potential environmental reductions associated with cropping in comparison to animal farming and the opportunity to diversify their risk in a changing landscape.

Furthermore there is opportunity for NZ meat processors to invest in cultured meat technology. This will enable them to diversify their product range into the alternative protein market, and potentially future proof their businesses.

Invest
The alternative protein technology is progressing at a rapid pace, and this is largely as a result of the millions of dollars that are being invested in this area annually. In order for NZ agriculture to remain viable in the future, we need to continue to invest in our own research and development.

Areas of focus should be although not limited to: reducing greenhouse gas emissions from agriculture, carbon sequestration, water quality, improving animal welfare on farm, methods of animal/product traceability, health benefits of grass-fed meat, and understanding cropping of plant proteins and what grows best in NZ. Continuing to invest in understanding our markets and the marketing of our products will also be beneficial to the industry, in order to maximise the best value from our products.

Investment into our communities is also essential in order to support farmers to adjust to the changing farming landscape and also to assist with breaking down the rural urban divide.

There are a lot of exciting opportunities for NZ agriculture that need to be actioned now. In order to remain profitable and sustainable in to the future, NZ agriculture needs to work on being the best that we can be in terms of our systems and practices. We need to work collaboratively both as a country and as an industry to market our products with a strong natural, grass-fed message.

We need to target our products to the markets willing to pay the highest prices for these and continually look for opportunities to add further value to these products. Furthermore we should look for opportunities to diversify our farming and meat processing operations. Lastly we need to continually invest in NZ agriculture, market research and our communities in order to future proof our industry.

For the purposes of this report, NZ beef will be the segment of NZ Agriculture that will be focused on for the lifecycle analysis section. This segment was chosen as it provides the best comparison for cultured meat, and data was readily available.

12. NZ Beef

The role of beef cattle in NZ farming

First introduced into NZ in 1814, cattle quickly showed their versatility for grazing areas unsuitable for sheep. Today, breeding-cow herds are usually located in high country, hard and medium hill country, land that isn't suitable for growing crops and cannot be harvested.

Complementary to sheep, cattle maintain and improve pasture quality and graze poor-quality pasture where sheep would not thrive. Cattle also have an important role in 'cleaning up' pasture by eating the larvae and eggs of internal parasites that infect sheep, but do not harm cattle (Peden, 2008). In New Zealand, few farmers exclusively farm for beef production, generally the raising and finishing of beef cattle is carried out in conjunction with sheep farming. On New Zealand hill country, farms that stock both sheep and cattle are usually more productive than those with just one or the other.

Beef production

Beef production encompasses cull dairy cows, bobby calves and raising young bulls to produce bull beef. New Zealand beef has two main end uses: 'prime beef' or table beef, produced from steers, heifers and bulls; and 'processing' beef (used in hamburgers) from older bulls, cows, and the forequarters of steers and heifers. Statistics from Beef and Lamb New Zealand (2018b) showed that total beef and veal production for the year to September, 2017, was 633,000 tonnes, with approximately half of the beef and veal exports from New Zealand destined for the US market.

Without beef animals coming from the dairy industry New Zealand's beef production could not be maintained at present levels. New Zealand's beef breeding herd of 1 million cows does not produce enough replacement animals to maintain the national herd of 3.61 million and the 2.4 million adult cattle that are slaughtered each year. Indeed, cattle bred in the dairy industry contribute around 50% of New Zealand's beef production, including Friesian bulls, dairy-cross beef cattle, and surplus dairy cows. Annually, around 1 million bobby calves from the dairy industry are hand-reared and finished as bull beef.

Environmental Footprint

New Zealand beef has a relatively low carbon footprint compared with other countries, largely due to the sourcing of beef from the dairy industry as mentioned above. This method of using "by-products" from the dairy industry results in a very efficient carbon footprint – more efficient than traditional beef because it doesn't need a breeding cow producing a calf to grow it.
Absolute emissions for the sheep and beef sector have been steadily declining for more than 20 years and are currently sitting 30% below 1990 levels, (Beef and Lamb NZ, 2018b), and this is mainly attributed to increased animal productivity.

The environmental footprint of NZ beef will be assessed in the next section, using a life cycle assessment to compare NZ Beef with Cultured Meat.

13. Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA; Guinée et al., 2002) is a key tool for evaluating the environmental efficiency of a whole-system. It enables evaluation of the resource inputs and environmental emissions throughout the life cycle of a product so that the key "hot-spots" can be identified and the most effective options for improvement defined. This starts from the extraction of raw materials and includes all aspects of processing and transportation. (Ledgard et al., 2012)

Over the past decade LCA has been used in agriculture to focus solely on climate change and its use for estimating the carbon footprint of products, i.e., the total greenhouse gas (GHG) emissions throughout a product's life cycle. However, with the concerns about energy resources, fresh-water availability and water quality deterioration, there has been a recent interest in using LCA in research on these other key resource issues. (Ledgard et al., 2012).

14. Methods

The method used for this study was to review lifecycle assessment (LCA) data for both cultured meat and NZ Beef.

Here LCA is used to quantify the lifecycle GHG emissions associated with cultured meat and New Zealand beef using 100g as the functional unit. Carbon dioxide equivalent (CO_2e), the international standard metric for measuring and reporting GHGs, is used to normalize the global warming potentials of different GHGs so that they can be readily compared. These GHGs include Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous oxide (N_2O).

The CO_2e metric weights each GHG according to its global warming potential (GWP). For example, CH_4 and N_2O have significantly larger GWP than CO_2, 25 and 298 times CO_2, respectively, when considered over a 100 year time horizon. In addition, the water footprint and land use were also compared for cultured meat and NZ beef.

Data were obtained from scientific papers produced by key scientists in these areas (Cultured Meat, Tuomisto, 2011; GHG Footprint, Lieffering, M. et al., 2012; and Water Footprint, Zonderland-Thomassen, M. et al., 2012).

Data from the Water foot printing study (Zonderland-Thomassen et al., 2012) of NZ sheep and beef meat were based on two surveys; a Beef and Lamb survey of different sheep and beef types (farm classes 1-7) from 2009/10. Data for the processing stage was based on an energy and water benchmarking survey by AgResearch on behalf of the Energy Efficiency and Conservation Authority (EECA) and the Meat Industry Association (MIA) for the 2010/11 years.

New Zealand beef cattle numbers and their associated land use were estimated based on data extracted from the Beef + Lamb New Zealand Compendium of New Zealand Farm Facts for 2018 (Beef + Lamb New Zealand, 2018b).

To compare the two LCA studies, the functional unit (FU) was recalculated. In addition, LCA results were expressed in the same unit and were recalculated to a cradle to meat processing gate LCA. Of particular importance was ensuring that the NZ beef comparisons excluded any bone weights, as these are not present in cultured meat.

Functional Units

The functional units for this study are defined as 100g of boneless uncooked meat to the meat processing gate.

System boundaries

This study represents a cradle to processing gate assessment of the NZ beef and cultured meat product chain. The study excluded packaging, and activities at the retail and consumer level. This cradle to processing gate boundary was chosen primarily because especially given the uncertainties present in generic modelling of these downstream stages, retail and consumer activities are likely to be equivalent between the NZ beef and cultured meat product systems. Also because cultured meat is still in the research stage and not currently available for purchase, the processing gate was deemed a sensible boundary.

Allocation decisions
Biophysical allocations was used to determine which portion of the emissions should be allocated to meat versus other outputs including hides, offal and tallow. Biophysical allocation was attributed between different animal types on farm based on the amount of feed consumed. Economic allocation was used at the meat processing stage between meat and non-meat products.

Impact Categories
The impact categories chosen for this study include: Greenhouse gas emissions (global warming potential), water use and land use. These impact assessment categories were chosen to coordinate with those used by both the New Zealand beef LCA studies and that of the Cultured Meat LCA study. Brief descriptions of the impact assessments methods are provided for background:

- *GHG:*
  GHG is made up of emissions of Carbon Dioxide (CO_2), as well as methane and nitrous oxide converted to CO_2 equivalents, using known fixed conversion rates known as Global Warming Potential (GWP) factors.

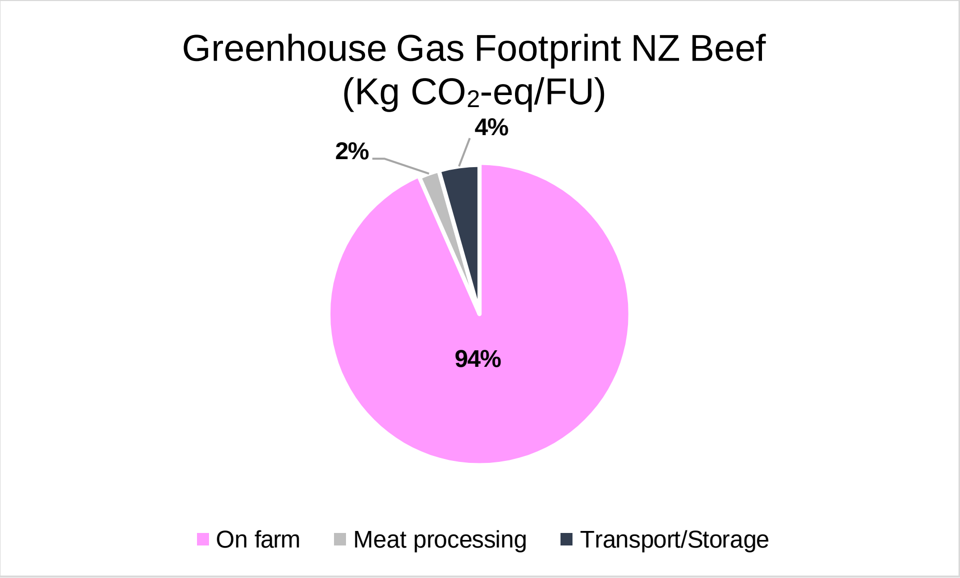
- *Water use impact:*
  Water footprinting is made up of blue, green and grey water evaluations. Blue water footprint is the volume of groundwater and surface water consumed, that is withdrawn and then evaporated. Green water is the volume of water evaporated from soil. The grey water is the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. Only blue and green water footprints were utilised in this report. For NZ beef the values used were weighted averages from 7 farm classes.

- *Land use impact:*
  This impact assessment is the amount of occupied land from a simple land use inventory perspective. In order to work out land use for Beef, the respective proportions of sheep to beef had to be calculated in order to estimate the land area specifically related to beef only. Beef stocking rate was estimated to be 4.5 stock units.

15. Results/Analysis
The carbon footprint of NZ beef averaged 2.12 Kg of CO_2-eq/100g of beef meat, with 94% from the cradle-to-farm-gate (mainly animal methane and nitrous oxide emissions), 2% from meat processing, and 4% from all transportation stages (predominantly from shipping) as shown in Figure 5.

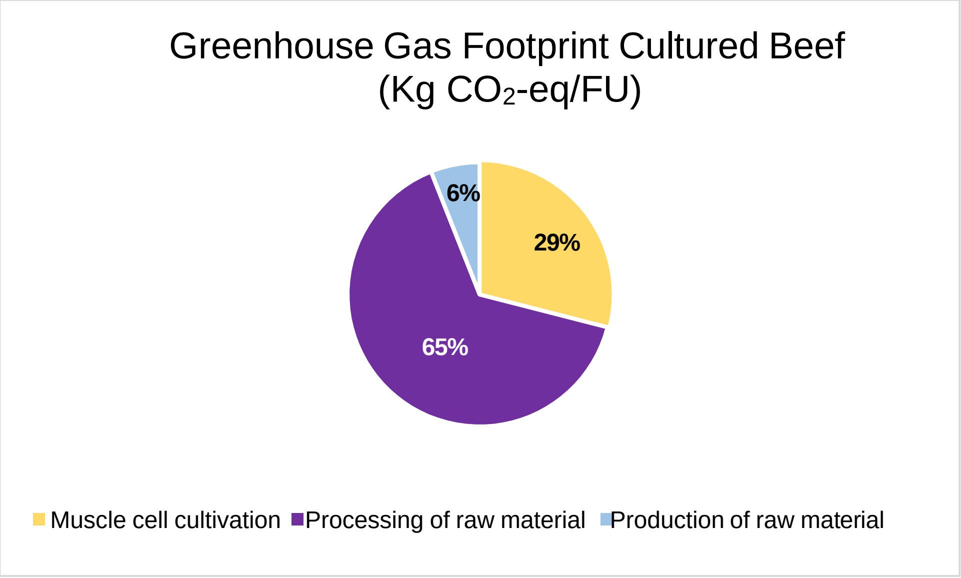
For New Zealand Beef, the on-farm stage has the greatest contribution to greenhouse gas emissions. The majority of this was derived from natural processes associated with cattle consuming pasture – enteric methane from rumen digestion (62%) and nitrous oxide from animal excreta on soil (17%). In contrast, electricity use contributed less than 0.3% of the on-farm footprint. The NZ beef water use footprint for blue and green water combined was $8.76m^3$/100g, whilst land use was $4.28m^2$/100g.

Figure 5. A graph showing the greenhouse gas footprint across the on-farm, meat processing and transport stages for NZ beef



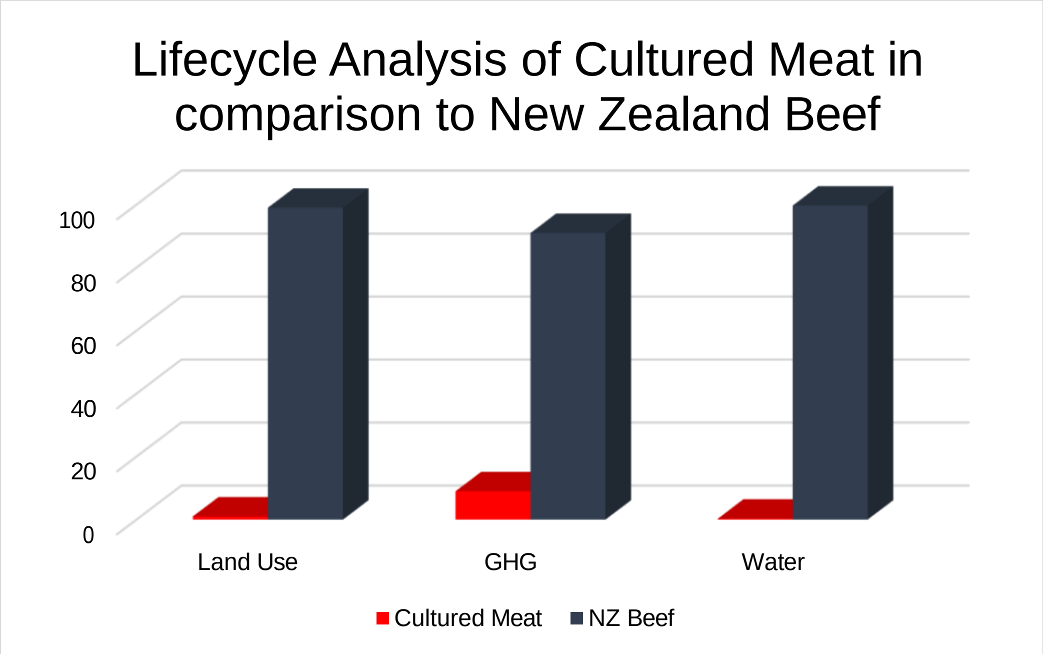
In comparison, the carbon footprint of cultured meat averaged 0.207 Kg of CO_2-eq/100g of meat, with 29% from muscle cell cultivation, 65% from the processing of raw material, and 6% from production of raw material as shown in Figure 6.

Figure 6. A graph showing the greenhouse gas footprint across the muscle cell cultivation, raw material processing and production stages for cultured beef



Total water use, GHG emissions and land use of producing 100g cultured meat in comparison to New Zealand Beef are presented in Figure 7.

Figure 7. Comparison of greenhouse gas (GHG) emissions, land use and water use of cultured meat production with New Zealand Beef per 100g edible meat as a percent of the impacts of the products.



For cultured meat, the production of cyanobacteria accounts for approximately 28% of GHG emissions and 17% of indirect water use. The cultivation process of muscle cells has the greatest contribution to the results, accounting for 71% of total GHG emissions and 82% of indirect water use. The highest water input was needed for replacement of evaporation loss in cyanobacteria cultivation (blue water). Total water use for the blue and green water footprint of cultured meat averaged $0.0210m^3$/100g. Transportation was a minor contributor to the results. The land requirements for producing feedstock for cultured meat production vary according to the location of the facility but averaged $0.0215m^2$.

16. Discussion

As shown in Figure 7, the land and water use, and GHG emissions for cultured meat are substantially lower than New Zealand Beef. The cradle- to-farm gate stage was the main contributor to the carbon footprint of NZ Beef, and this was predominantly from animal-related methane and nitrous oxide emissions (comprising 94% of the total carbon footprint). Thus, the largest opportunity to reduce GHG emissions on-farm is to increase the efficiency of feed conversion in beef meat.

GHG emissions were also the main contributor to the carbon footprint of cultured meat, the majority of which are associated with the use of fuel and electricity. These emissions could be further reduced by using renewable energy sources (Tuomisto, 2011).

On farm
On farm the largest contributors to the GHG footprint are natural processes associated with cattle consuming pasture. These processes produce methane from rumen digestion of pasture (via belching, 62% of total footprint) and nitrous oxide from animal excreta on soil (17% of total footprint). The on-farm component of the beef meat GHG footprint can be reduced via management practices that increase the conversion of pasture to meat thereby reducing the proportion of pasture consumed to “maintain the herd”.

Scenarios run by Lieffering et al., (2012) examined a range of management options that could reduce the GHG footprint of beef on-farm, with the two most promising practices being rearing young stock from the dairy stock and improved growth rates from bull beef compared to steers or heifers. These two practices resulted in reductions in farm related GHG emissions of up to 30%.

Emissions from external inputs to farms e.g. fertilise, fuel and electricity were low and this is largely attributed to the low intensity and low input nature of beef farming in NZ. Electricity use for example contributed less than 0.3% to the total footprint, which can be attributed to both low electricity usage and also because 80% of New Zealand's electricity generation is obtained via renewable sources. Also Nitrogen fertiliser use is very low in New Zealand sheep and beef farms in comparison to intensive overseas farming systems. As a result NZ beef farmers benefit from the clover plants present in pastures to fix atmospheric nitrogen and produce no direct GHG emissions.

Bull calf rearing contributed 62% to the blue water footprint, mostly due to the water footprint associated with the use of milk powder, whereas blue water losses from evapotranspiration from irrigated pasture contributed 32%. Losses from evapotranspiration from pasture contributed 96% the green water footprint.

Meat processing
The GHG emissions associated with meat processing were very low, making up only 2.1% of the total beef GHG footprint. This was made up of energy use and wastewater processing. Electricity and other fossil fuels are used to produce hot water and steam production, and electricity is mainly used to refrigerate or freeze meat, operate machinery, for lighting or wastewater treatment. Methane and nitrous oxide are emitted during some wastewater processes. The main areas to improve from the meat processing perspective include reducing the use of fossil fuels (coal), and using aerobic treatment systems for wastewater processing.

Transport and Storage
Oceanic shipping of beef in refrigerated containers from NZ to overseas destinations made up about 2.6% of the total footprint, and is the main contributor (61%) to the transport and storage stage. While an important source of emissions, the relative size of the shipping contribution to the footprint highlights that transportation distance influences only a small fraction of the overall footprint and negates overseas marketing claims around food miles associated with New Zealand products.

How does this compare to other LCA studies?
It has been found that generally beef has the highest environmental impacts whereas poultry has the lowest impacts when different species are compared (deVries & de Boer, 2010; Tuomisto & Teixeira de Mattos, 2011). In addition many meat substitutes been shown to have a lower ecological footprint in terms of carbon footprint, land use and energy use (Nijdam et al., 2012).
The low impact of transport on the total footprint of NZ beef reflects the findings of Saunders et al, 2007) who showed that the greenhouse gas emissions of NZ dairy products shipped to the UK contributed approximately 9% of the total greenhouse gas emissions.

Although beef and other red meats have a greater carbon and land use footprint than cultured and white meats, there are context issues and other environmental indicators that should be considered in assessing the wider sustainability of food products. Pigs and poultry are generally fed on grains from crops on land that could alternatively be used for crops for direct consumption by humans.

In contrast, ruminants can utilise feed sources that cannot be utilised by non-ruminants, and in the case of sheep and beef this is largely grassland that is on land unsuitable for cropping. In New Zealand, beef for example often graze steep hill country that is generally unsuitable for other food production purposes.

Additionally, many pastoral ecosystems, depend upon grazing ruminants for their maintenance; this is an example of an "ecosystem service" that cattle provide or help support. Biodiversity is another feature of landscapes grazed by sheep and beef. In NZ most sheep and beef farms have significant areas of native bush or planted trees, particularly on steeper slopes. There is currently no method within carbon footprint analyses to offset GHG emissions, however at an individual farm and national GHG inventory level these recently forested areas represent significant carbon sinks.

Furthermore carbon sequestration is also not taken into account. Surveys of soil carbon status on sheep and beef farms on NZ hill country have shown that amounts are increasing (Schipper et al., 2010) however more research is required to understand the processes affecting carbon accumulation before it can be included in carbon footprinting measures.

The life cycle analysis shows that the environmental footprint of cultured meat is very small. However there is a level of uncertainty around whether these estimated environmental impacts will be able to be achieved particularly given cultured meat is still in the development phase.

NZ Agriculture may not be able to reduce our environmental footprint to those estimated in this report for cultured meat, but there are some clear areas for improvements. These are as follows:

- Further research in to the greenhouse gas emissions of animals on farm as this has the greatest impact on NZ's greenhouse gas contribution, in particular enteric methane.
- Continue to work on animal efficiencies - such as NZ beef utilising bobby calves from the dairy industry, and working to increase efficiencies in feed conversion to enable animals to reach target weights earlier and therefore reduce the time spent on farm.
- Work to get biodiversity recognised as an indicator in Life Cycle analysis in order to gain "credits" for NZ's unique biodiversity on sheep and beef farms.
- Further work should be done to show the differences in footprints between NZ farming systems and American farming systems for example, in order to demonstrate the efficiencies of NZ farms in comparison to overseas, which will help to differentiate our products in the market.
- Diversification – by reducing the number of animals on farm, and substituting this with crops for plant proteins there will be reductions made to the overall farm component of the footprint
- Whilst the environmental footprint doesn't compare – there are other benefits that can be demonstrated and utilised for promoting NZ beef including providing jobs for over 6% of the population, biodiversity, and grazing areas of land that cannot be utilised for cropping to directly feed humans.

17. Conclusions

Despite high uncertainty, it is concluded that the overall environmental impacts of cultured meat production are substantially lower than those of conventionally produced NZ beef. Cultured meat is still in the development phase, so it is too soon to know whether the estimated environmental impacts presented here will be able to be achieved, or whether cultured meat will even be able to scale, reduce in costs, or overcome consumer reservations about eating "fake meat" to be a viable competitor to NZ Beef.

However what is known is that large sums of money are being invested into cultured meat and scientists working on this technology predict it will be in market within the next 5-10 years.

Given the shortfall in the current food supply predictions to feed the worlds growing population by 2050, I believe there will be room in the market for both alternative proteins and traditionally farmed meat.

Nevertheless there is an increasing awareness of the impact of agriculture on the environment, on animals and on human health, which NZ Agriculture needs to stay abreast of.

18. Recommendations

In summary, in order to remain profitable and sustainable in to the future NZ agriculture should action the following opportunities as identified in this report:

- Improve Transparency and Traceability
  Work on being the best that we can be in terms of the transparency and traceability of our agricultural systems and practices.

- Work Collaboratively
  We need to work collaboratively both as a country and as an agricultural industry to market our products with a strong natural, grass-fed message

- Target Specific Markets
  We need to target our products to the markets willing to pay the highest prices for these and continually look for opportunities to add further value to these products

- Seek opportunities to Diversification
  We should look for opportunities to diversify our farming and meat processing operations

- Continue to Invest
  Lastly we need to continually invest in NZ agriculture, market research and our communities in order to future proof our industry

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