UNIVERSITY OF CANTERBURY

ENME418 Engineering Management

Feasibility Study

Dairy shed manure collection for methane and methanol production through on-farm bio-processing

A Methanex New Zealand Limited Company Venture

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1. Executive Summary

Methanex is proposing to enter the market to produce methanol from biogas, more specifically bio gas retrieved from New Zealand dairy farms. The project proposed will make use of existing steam reforming technologies but will look to develop them to a state where they are more efficient and can be conducted on a smaller scale. This technology will then be applied to processing plants which will have methane supplied to it directly through pipes from around 10 farms. This eliminates the need for transportation of methane or the construction of a separate nationwide system across New Zealand connecting dairy farms to a large scale processing plant, which for a variety of legal, social, environmental, political and economic reasons would be hard to achieve. The report will focus on the feasibility of the project focusing on the establishment phase of the project right up to bringing the system to market and initial growth phases.

The initial phase of the project before any systems other than the prototype are implemented is expected to last about 2 years and 9 months and cost $3,225,620.84. This phase of the project will be carried out by both full time employees and contacted staff. During this phase recruitment for additional personnel is undertaken.

It is expected that 60 plants will be established in the first 10 years after the project hits the market, after 21 years the project is predicted to make $8,333,947.43 profit after tax and a cumulative profit of $48,489,988.19. The whole project is projected to break even after 17 years. Optimistic projections project that the project will break even in 12 years and achieve a cumulative profit of $472,540,251.54 after 21 years, whilst pessimistic projections predict that the project will never make a cumulative profit. The NPV predictions were $73,095,635.36 for an optimistic projection, -$20,007,942.99 for an expected projection and -$35,288,118.04 for pessimistic market predictions.

For that reason the project has been shown to be a high financial risk. Significant risks include product and market failure. Opportunities included high profits from good sales and positive public image due to the projects environmentally friendly nature.

The financial benefit for the farmer was shown to be $5,275 per annum for the money saved in fertiliser, not including tax rebates and increased value in product. The main financial benefit from implementing the systems would be selling the methanol produced from methane, and this would be the main selling point to investors. The main selling point to government and local population would be the environmental benefits this system would bring. Not only would it provide the world with a renewable material, but it would reduce the amount of methane released into the atmosphere from New Zealand dairy farms.

The project presents no major environmental concerns. There could be potential for noise and visual pollution concerns, however these are considered to be low risk concerns.

A non-discloser agreement should be signed by all staff and contractors to maintain the security of the project. Patents should be applied for any new technologies founded during the project to secure intellectual property rights for up to 20 years.

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2. Introduction

This report investigates the feasibility of implementing bio-processors to turn manure collected from Dairy Farm sheds into biogas. The biogas will then be piped to a centralised processing plant to turn the methane content of biogas into high value methanol by steam reformation processing. The venture will be conducted as a new project for Methanex New Zealand Limited, which is New Zealand's only methanol manufacturer, with three production facilities providing the capacity to produce up to 2.4 million tonnes of methanol annually from Taranaki natural gas feedstocks. Approximately 95 per cent of the methanol it produces is exported to the Asia Pacific region. Methanex use methanol to create high value product. Methanol is the building block for countless everyday products and can also be used as a clean-burning alternative source of energy.

This report investigates the potential reduction in costs and emissions for dairy farmers with the implementation of this system. Manure will be collected from dairy sheds and broken down in a bio processor using bacteria. The methane expelled will be collected and piped to the centralised processing plant.

The by-product of the biological process is a nitrogen rich substance suitable for use as a fertiliser. This is part of the company's marketing material, as there is an opportunity for farmers to reduce costs and environmental impacts from fertilisers.

The company will sell the proprietary technology to farmers, who will provide the biogas produced by the bio-processor. The biogas is piped from 10 surrounding dairy farms to a centralised plant where the methane component of the biogas undergoes an oxidation process to form high value methanol. Methanol is also a liquid at room temperature and pressure, making it a lot more convenient for storage and transport than methane gas. While each of these technologies are not completely novel on their own, the implementation of the system in the context of renewably sourced dairy farm biogas is one that has not been previously investigated before, and has many factors that mean it is suitable for application in the New Zealand environment.

3. System Architecture

3.1 The Concept

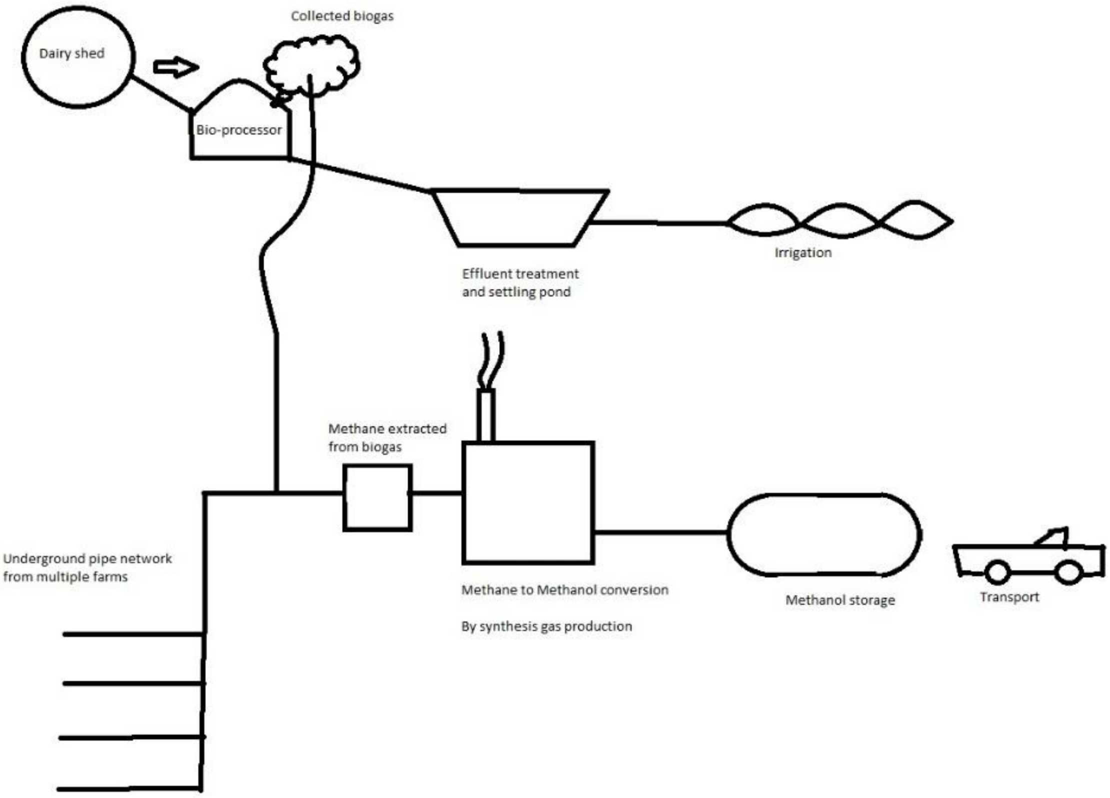

Figure 1: Methanex biogas venture concept

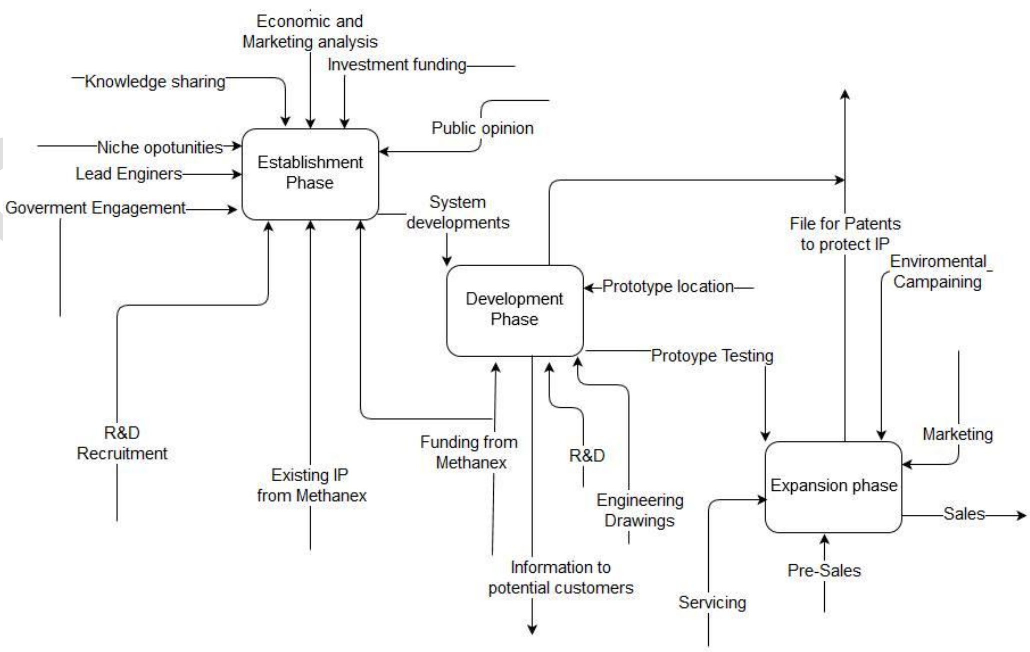

Figure 2: IDEFO diagram of the concept

3.2 The company

Methanex’s highly skilled and diverse workforce in New Zealand includes approximately 250 employees with additional support from local contractors. Methanex is an important contributor to the local and national economy. In 2013, an economic report prepared by Business and Economic Research Limited forecast that Methanex contributes NZD440 million to Taranaki's GDP and NZD650 million to New Zealand’s GDP annually at full production from its existing natural gas fed plants.

Methanex New Zealand’s team members are committed to the principles and ethics of Responsible Care, consistently exceeding the requirements laid out by local and central government. [1]

The New Zealand dairy farming sector is an obvious source of abundant biogas, which is composed of 60% methane and 40% carbon dioxide. It is the intention of this new company venture to exploit the business potential in this abundant source of eco-approved energy.

4. Risk Assessment

4.1 Introduction

A detailed risk assessment was carried out on methanol production through on farm bio-processing. The assessment was undertaken to analyse the risks of the project undertaken by Methanex New Zealand Limited. Opportunities as well as threats to the venture where investigated. The risk assessment was carried out in full accordance to ISO31000:2009 “Risk Management – Principles.”

4.2 Scope

Six key areas where taken into consideration when undertaking the risk assessment. Each area has its own specific objective.

Key Area	Objective
Political	Gain political support on a regional and national level for the project in the form of publicity or money.
Economical	Minimise manufacturing and distribution costs, as well as ensuring the financial wellbeing of the project is safeguarded.
Social	Ensure that in all aspects of the venture the effects on local communities are considered.
Technological	Ensure that the product is durable, of a high standard and does what it was designed to do.
Environmental	Minimise harm to the environment and comply with all the relevant sections of the Resource Management Act (RMA, 1991).
Legal	To comply with all relevant laws in New Zealand and to reduce product liability as much as possible to create a device that can easily insured.

4.3 Analysis

Each risk was analysed and given an assessed risk level and placed on the risk map. The full results of the risk analysis can be found below.

4.4 Risk table

Colour Key	Risk, Threat or Opportunity	Who should be informed?	Action Required
	High Risk Loss	Directors	Requires senior management to design deliberate treatment action plans and specified responsibility.
	Medium Risk Loss	Top Management	Attention of senior management needed to develop specific response or monitoring procedure , and the specification of management responsibility
	Low Risk Loss	Immediate supervisor	Manage with routine procedures, no specific extra resources required
	Negligible Risk or Gain	Work Team	Business as usual. Manage with routine procedures and general monitoring
	Low Opportunity	Immediate Supervisor	Manage with routine procedures or specific monitoring
	Medium Opportunity	Top Management	Attention of senior management needed a management responsibility specified.
	High Opportunity	Directors	Detailed planning required at a senior level to prepare for and capture opportunity

Figure 3: Risk Register Key

Approx. Frequency (Per Year)	Description	Likelihood	Negative Risk Area (Threat)						Positive Risk Area (Opportunity)				
1	Annual Occurrence	Almost Certain									33		1
1/3	Has Occurred Several times in a lifetime	Likely			30	19, 25	2				6, 10, 22, 28	4, 18	3, 11, 32
1/10	Occurred once in a lifetime	Possible		31	24, 26	23, 27					5, 14	17	7, 13, 34
1/30	Occurs somewhere from time to time	Unlikely	8, 15, 37										
1/100	Heard of it happening elsewhere	Rare	36	12, 29		21							
1/1000	Have never heard of it happening	Very Rare	16, 28	9	35								
1/10000	Theoretically possible but not expected to occur	Almost Incredible											
		Consequences	Severe Loss	Major Loss	Moderate Loss	Minor Loss	Negligible Loss	Neutral	Negligible Gain	Minor Gain	Moderate Gain	Major Gain	Huge Gain

Figure 4: Risk Register Results

5. Project plan

5.1 Introduction

The Project has been broken down into three phases. Each phase has been broken down into a number of key sections.

5.2 Discussion of project plan

1. Establishment phase *07/09/2016 – 09/10/2017*

The first of three phases is all about building relationships with the relevant groups in New Zealand as well as continuing improvement of system components with the mind-set of establishing a prototype system.

- **Prioritising Goals:** Decide what goals the project wants to achieve.
- **Economic Analysis:** Investigate New Zealand and International applications of biogas methanol production, compare project to existing systems to explain benefits and cost.
- **Market Analysis**: Investigate the biogas market in New Zealand, focusing on utilising manure from dairy farms. Focus initially on current potential economically viable sites with incentives from local government to pursue this type of project. Keep an up to date directory on market developments.
- **Knowledge sharing:** Inform and share knowledge to government (local and national) as well as Farmers who could potential benefit from system.
- **Funding of Project:** Look to secure funding for project, first looking towards government to see if there are any cash incentives that can be utilised, then finance the rest of the project through investors or company capital.
- **Regulations:** Engage with law makers and regional councils to inform them of the benefits of the proposed system. Find out what laws and regulations the project would have to comply with.
- **Government Engagement**
    - **i.**Energy point of view:
        1. Potential for tax breaks for eco-friendly biofuels

        2. Fuel security of New Zealand
        3. Government pledge for 90% renewable energies by 2025
        4. Clean heat codes and regulations
        5. Emissions trading Scheme

    ii. Environmental point of view:

        1. Waste management bill
        2. Biogas capture mandates
        3. Farm waste management codes
        4. Local government guidelines

- **Build public opinion:** Invest in gaining public support for the project from an environmental standpoint
- **Research and development:** R&D Methods of improving efficiencies and techniques used in the system.
- **Niche opportunities**: Identify niche opportunities that occur in New Zealand's unique dairy industry

2. Development Phase *09/10/2017 – 03/06/2019*

The development phase of the project primarily focusses on establishing a prototype system involving around 10 farms. It also focuses on proving that the system is beneficial for the farmers involved in the business and for New Zealand as a whole.

- **Demonstration of system:** Showcase the potential system as well as the uses for methanol e.g. motorised transport, electricity generation.
- **Developments of tools and guides:** Development of techniques and tools to maximise efficiency of system processes.
- **Rollout:** Set up prototype system operating on a group of 10 farms.
- **Trans-regional partnerships:** Push for partnerships between regions in using and transporting methanol product.
- **Good agricultural practice:** Push for environmentally friendly practices like cleaning up streams, look for solutions to the problem of effluent run-off and disposal.
- **Market Analysis:** Establish potential for mass roll out of biogas recovery systems. If not already achieved in phase 1, find economically viable sites for systems across North Island.
- **Research and development programmes:** Strive to improve efficiencies of techniques to maximise economic potential.

3. Expansion Phase *04/06/2019 – 08/09/2027*

The third and final phase of the project is expanding the project across the whole of New Zealand by capitalising on the planned success of the prototype system. A continuation of investment into R&D to minimise maintenance costs for existing systems will also take place.

- **R&D Support mechanisms and regulation:** Set up network to support existing systems to try and minimise maintenance costs.
- **Natural Gas network for biogas:** Set up or join a natural gas network spanning across the North Island.
- **Substitution of fossil fuels:** Push for increased methanol usage across New Zealand.
- **Rural sector scale-up:** Push for mainstream roll out among New Zealand Dairy farmers.

6. Financial Feasibility

6.1 Introduction

Manure collection has not typically been practised on New Zealand dairy farms. However, if there is the opportunity to collect manure to help comply with increasingly stringent effluent disposal regulations, as well as potentially harvest energy from the methane gas and reduce odours, the company believes significant interest will arise from the dairy community. In addition, there are possibilities to use the high nitrogen contents of the manure to re-spread the collected manure, through existing irrigation equipment, to reduce dependency on externally sourced fertiliser.

The company aims to create a contract with the farmers, who will purchase our equipment, to collect the methane from the biogas and create high value methanol for distribution to local and international companies for use as a base ingredient for many chemicals, bio-fuels, pharmaceuticals and other high-value products. This will be done through a centralised steam reforming plant, taking the biogas production of ten nearby dairy farms and steam reforming the methane into methanol, which is more easily stored and transported as it is a liquid at room temperature and pressure.

The company will pay for the installation of the bio-processors on the farms. The benefits to the farmer include an improved environmental status as a result of reduced methane emissions and reduced effluent run off, as well as a reduction in fertiliser costs. Overall farm efficiencies will be improved through the implementation of these systems.

The first operational plant, other than the prototype system, will be finished in 2019. The financial outlay up until this point will be $4,539,540.76.

6.2 Methanol plant

The methanol plant will be set up to process the biogas produced from ten farms. The expected feedstock from the dairy farm supply is 4.71 T/yr of methane. This is performed in the local New Zealand context with due considerations for environmental sustainability. The plant is designed assuming a 10-year plant life and 2016 hours of operation per annum.

Table 1: Financial Analysis Assumptions

Inflation	3%
Marketing and administration	2%
Tax rate	28%
Initial global methanol price	$391.6755/MT
Total material cost	$2.56 million per plant
Calculated labour cost for set-up	$341,000
Operational cost (maintenance + labour)	10% of initial outlay

Estimates of future profits were conducted based on three scenarios – optimistic, expected and pessimistic. This was conducted by adjusting the efficiencies of the methanol plant and inflation of the price of methanol in future years. Maintenance costs were calculated to be 5% of initial cost of plant set-up per annum and labour costs for plant operation after set-up were calculated to be 10% of initial labour outlay. A plant overhaul, costing 50% of the original construction and labour costs, was carried out after 10 years to achieve another 10 years of service life. No new plants were commissioned after 10 years of company operation.

Assumptions that apply to each individual case are listed below:

Table 2: Assumptions for optimistic cash flow

Optimistic
Plant efficiency 30% (conversion of methane to methanol)
Peak Methanol Production of 17,053 MT/year
No unexpected outages
Constant methanol price inflation of 2% per annum
Currency inflation of 3% per annum
100 plants in 10 years

Table 3: Assumptions for Expected Cash Flow

Expected
Plant efficiency of 20% (conversion of methane to methanol)
Methanol Production of 11,370 MT/year
1 unexpected outage of 3 month duration
Constant methanol price inflation of 0%
Currency inflation of 3% per annum
60 plants in 10 years

Table 4: Assumptions for Pessimistic Cash Flow

Pessimistic
Plant efficiency of 15% (conversion of methane to methanol)
Methanol Production of 8,526 MT/year
2 unexpected outages of a total duration of 6 months
Constant methanol price inflation of -2% per annum
Currency inflation of 3% per annum
40 plants in 10 years

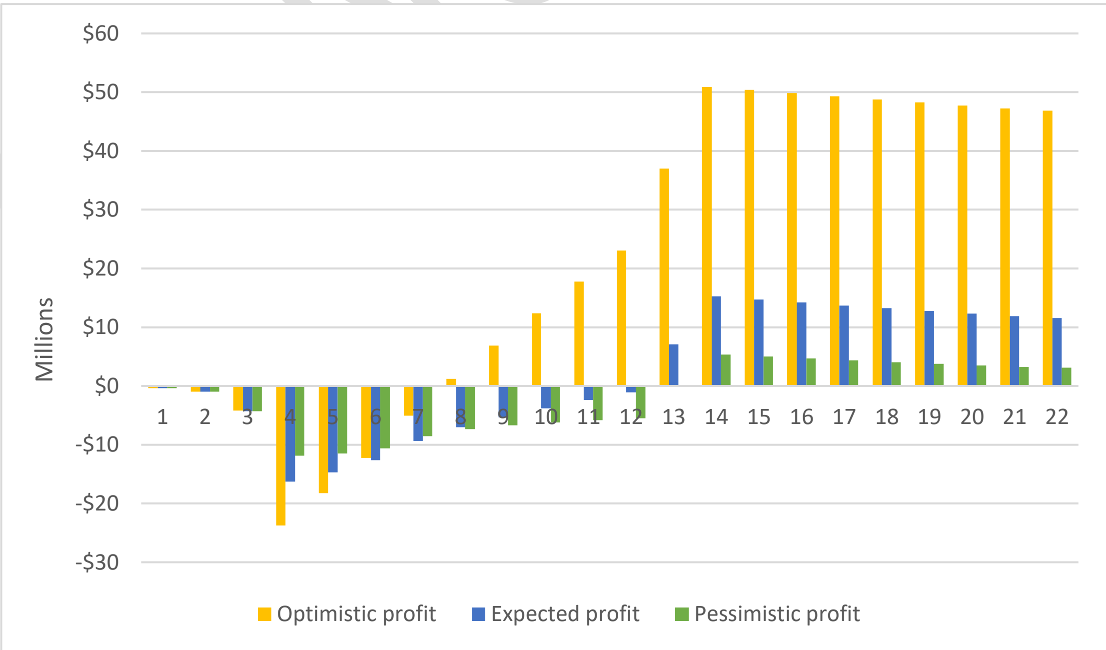

Figure 5: Company Profit per year

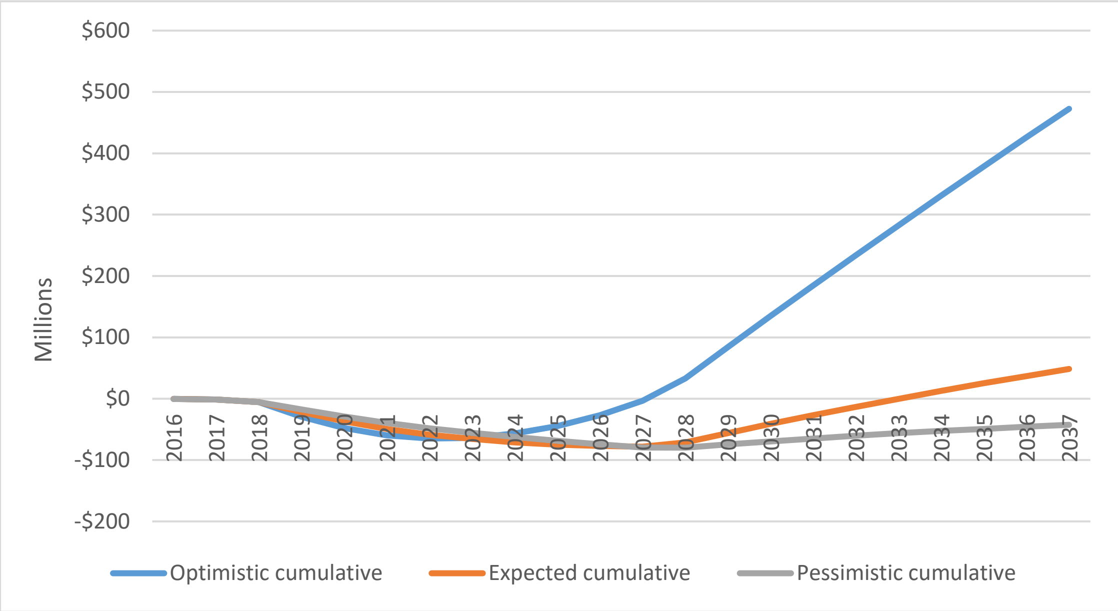

Figure 6: Cumulative Company Profit per year

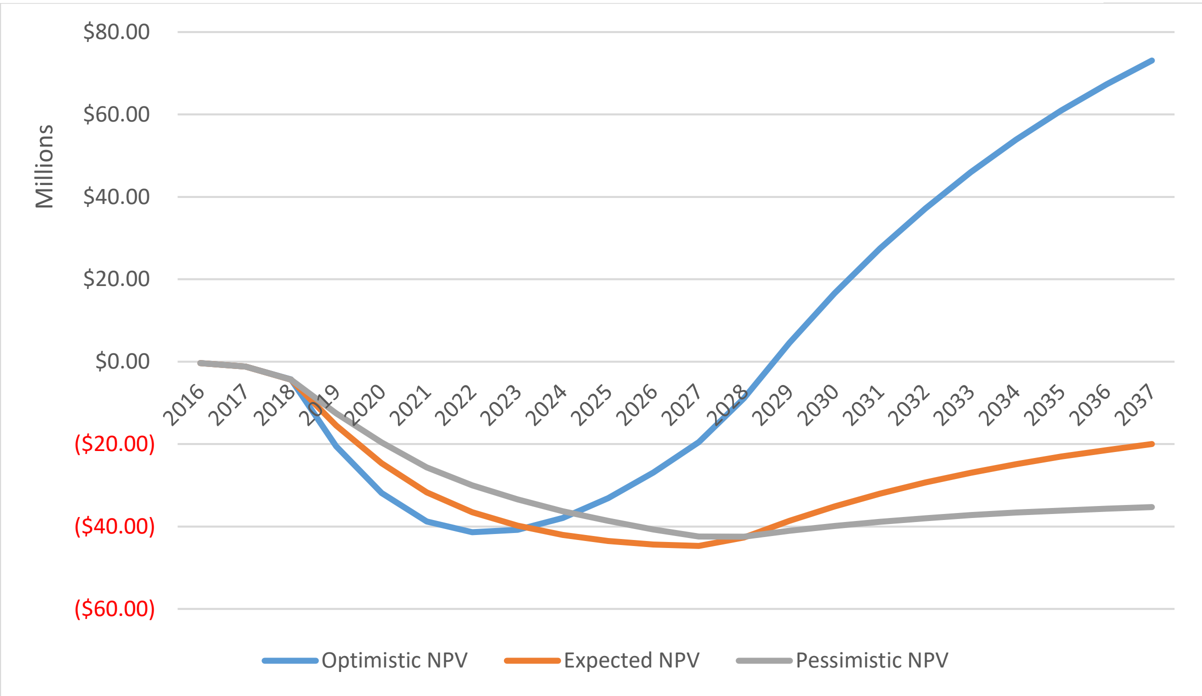

Figure 7: NPV

6.3 Results Summary

The table below outlines a summary of the statistics of the financials of the company.

Table 5: Overall Financial Statistics

Summary statistics	Payback Period	Net Profit
Optimistic	12 years	$473 mill
Expected	17 years	$49.6 mill
Pessimistic	-	-$41 mill (21 years)

6.4 Recommendations

From the above financial analysis it is apparent that the return for the country over 20 years varies depending on the ability to market the product successfully, as outlined in the predictions using optimistic, expected and pessimistic approaches. Seen as dairy farming is the largest section of the New Zealand agricultural sector, it is a recommendation of this report that the financial aspects for the expected outcomes of this venture are secure, considering the investment in marketing and technology that the company is undertaking. However, the net present value analysis displayed in figure 7 highlights that it would be best to invest the money in other ventures as an external investor, unless optimistic projections are met. There are however other benefits that Methanex New Zealand Limited will benefit from as a company operating in the local environment from investment in the biogas to methanol venture.

7. Route to market

7.1 Introduction

A successful marketing strategy is key to ensure a maximisation in profit. Successful marketing will ensure that all opportunities that present themselves can be fully capitalised and at the same time threats that may present themselves can be minimised. Relying on the quality of the product itself to influence sales is an unnecessary high-risk strategy. It is important to focus on strategy rather than the product itself. The marketing department of the project should constantly be up-to-date with emerging opportunities that may present themselves throughout the project. Possible key marketing achievements include the following:

- Support from local communities
- Support from local government
- Support from national government
- Attracting investors
- High sales

Threats that are minimalised by implementing a good marketing strategy are:

- Insufficient funds
- Community/Government backlash to the project
- Resource consent denied by government

7.2 Methodology

1. Selecting Target Market:

   Extensive market and economic analysis is to be undertaken to fully understand the dairy industry in New Zealand. This project targets dairy farmers with an average or above average size herd. The potential to save money as well as producing a "Greener" product are the selling points of this project, with emphasis on the "Greener" product aspect. This will mean that the product that the farmers are producing will be held in higher esteem and also appeals to farmers who are more environmentally minded. Because of this Methanex needs to drive hard the benefits of using dairy cow manure to produce fertiliser and methanol. Investors inside New Zealand are to be sought after the most, followed by other companies in the energy industry such as Contact or Meridian energy.

2. Product

Producing methanol from methane is a relatively well explored technology, producing methanol on the small scale that is suggested in this project is however new and innovative. R&D engineers will need to be hired to help improve existing larger scale components so that they can be scaled down and applied in an efficient and economically beneficial way.

3. Pricing

In this project the farmer does not pay for the system to be set up. In doing so they are agreeing to have the system set up on their farm, getting in return a “greener” dairy product as well as fertiliser for their fields. What Methanex gets out of this agreement is the methane produced by the manure. If this set up is not attractive enough to potential clients, deals can be struck that could see clients getting a return on the profits made my Methanex on their project. An extensive financial feasibility investigation is shown in a separate part of this report. This serves as the best research into pricing trends on methanol and expected turnover and profit of the venture. Market trends will be monitored to ensure a financially viable future for the project.

4. Promotion

The promotion is heavily linked with the success of the prototype project. The marketing strategy revolves heavily around the perception that producing methanol from dairy farms is hugely beneficial to the environment. Many high value opportunities identified in the risk assessment are linked to the promotion and the positive image. Dairy farming in New Zealand has many negative environmental connotations associated with it. It is therefore vital that this is used as an advantage when informing people about how producing methanol from methane is an activity which can help the environment and New Zealand’s green image. There are many ways of passing on information about the positives of this process:

- Local community meetings
- Presentations to industry leaders
- Presentations to the educational community (Schools, University’s etc.)
- Sponsoring of eco-friendly initiatives and events

The sub categories of the promotion phase of the marketing strategy can be broken down into the following sub categories:

- Positioning: What is the message that states the benefits of the product?
    - For Methanex the positioning is outlined above. For investors the potential to make a profit selling methanol made from bio fuels is the key benefit. It is also however very important to push forward how environmentally beneficial the project will be, this key fact will be crucial to winning over the general public as well as investors who are on the fence about investing. It is also key to convince farmers that the project will be beneficial to them in terms of money saved and the positive impact it will have on New Zealand
- Selling: Direct or indirectly through others?
    - There are two aspects to selling in the project:
        - **Selling the methanol:** Methanex already has an established catalogue of customers that it already supplies methanol to. There is an

    opportunity to sell the methanol made through this project at a premium because of its environmentally friendly manufacturing process. Methanex already has the logistical and sales resources to find additional customers to sell methanol too.
    - **Selling to farmers the idea allowing methane to set up biogas systems on their farm:** To achieve this Methanex will directly contact possible farmers via the public relations and marketing department which will be solely working on this project. The goal will be to convince the farmers that having free fertiliser and a greener product is worth having a biogas system on their farm.
- Communications: How will people be informed about the product?
    - The major goal of Methanex with this project is to inform the farming community about the benefits of having a biogas system on their farm. The success of the prototype system will be crucial in showcasing this throughout the project. Before and after prototype construction a sustained effort to recruit new farmers and spread information will be carried out in the form of advertising at farming events, information evenings and meetings.
- Support and service: How Does the customer get help if systems aren't performing?
    - The biogas systems on the farms will be owned and operated by Methanex, any repairs needed to the system are payed and budgeted for by Methanex, who will be taking an active role in the upkeep. Methanex is a well-established company, it has customer service systems in place should a farmer have any problems with the system.

To ensure that the marketing strategy listed above is implemented properly and successful, several things need to be formed within the project:

- **DMU (Decision making unit)**

  A DMU consists of all people within the project who play a role in any decision making on spending finances. The DMU's goal is to have successful communication between everyone with the unit.

- **DMP (Decision making process)**

  A DMP is the process which everyone in the DMU should follow, this process should be freely available and clear for everyone who reads it to understand.

7.3 Competitive Advantage

7.3.1 Definition

Competitive advantage is defined as an advantage that a company has over its competitors that it can leverage to obtain greater market share and profits, allowing it to be more successful in the market. Competitive advantage can be obtained through a number of methods, each of which have their own strengths and weaknesses.

7.3.2 Relevance

The success of the new Methanex venture depends very much on market uptake. Methanex must aim to create a sustainable competitive advantage with the methanol plants to achieve long term gain.

7.3.3 Resource based competitive advantage

Resource based competitive advantage operates on the principle of creating a rare, inimitable and valuable product. The creation of a service with these attributes will create a desire for market uptake and increase sales over competitors. Sustainable competitive advantage is difficult to achieve due to the high likelihood of change in one of the characteristics outside of the control of Methanex.

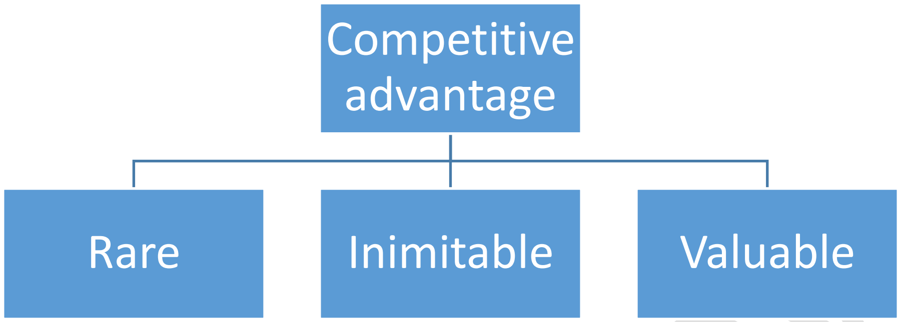

Figure 6: Resource based competitive advantage

7.3.4 Recommendation

It is recommended that Methanex focus on distributing the methanol produced from bio-gas through its existing network of methanol customers and even perhaps add a premium for the added benefit that the methane to create the methanol has been sourced renewably. The relatively high manufacturing and operating costs for this new venture of the Methanex Company render a cost leadership structure ineffective. Methanex must differentiate themselves from competitors. The nature of the venture is well suited to this seen as there is no commercial operation collecting biogas for methanol production operating locally or abroad. Methanex has an existing advantage as it already possesses the know-how of methane to methanol conversion via steam reforming. All it must do is successfully implement this process, using dairy farm biogas rather than natural gas feedstock. Therefore, if Methanex can simply commission and operate their methanol plants a competitive advantage will be created immediately.

7.4 Intellectual Property

7.4.1 Background

Intellectual property is usually enforced in the form of patents for technological ventures. They do not give the holder the right to develop a certain technology or invention, but rather exclude other parties from doing so. In this way, patents are an effective means to ensure competitive advantage as they enable the holder to develop a unique product or invention. Patents are usually valid for a period of 20 years, meaning that the advantage gained by the holder of the enforced patent is temporary, allowing others to implement the same technology after patent expiry. A patent can be sold, licensed, mortgaged, assigned, given away or abandoned.

7.4.2 Approach

A key activity during the risk assessment phase that was identified was obtaining protection for intellectual property. It is useful for maximising identified opportunities, such as maximising competitive advantage over rival companies and minimising threats. The process of steam reforming methane into methanol is already an established process that Methanex undertakes on a large scale using natural gas feedstocks. The biogas venture would simply involve extending the existing procedures and know-how of steam reforming that Methanex has for the new biogas context. There are existing patents surrounding these procedures that Methanex already holds or uses under license.

However, in terms of bio-processors, the system is relatively simple and there is a good opportunity to improve its efficiency through technological know-how. There is a threat that rival companies may have patents already complete or pending, meaning there may be an associated cost in terms of legal settlement to negotiate usage terms of the patents. This settlement will be in the form of royalties and would be paid to the patent holder in return for the use of the patented technology.

There is opportunity for multiple patents in the field of creating methanol from biogas due to the innovation that is possible. The technology has existed for some time however it has not been applied in this vain before, so there is opportunity to refine and improve the technology for more efficient implementation. This could lead to new patents from innovations that Methanex has created. Should the innovation prove to be un-patentable, Methanex should aim to maintain secrecy regarding their developments.

7.4.3 Current patents

New Zealand

The Intellectual Property Office New Zealand (IPONZ) which stores a database of all current patents in New Zealand contains a lot of patents on processing using methane. Examples of patents issued in the past in New Zealand involving methane and methanol include:

- Method for producing methane from biogas

This patent has expired since being issued.

Worldwide

There is a breadth of information available surrounding global patents involving the process of steam reforming to produce methanol from methane. The process is still being developed to improve efficiency. Listed in the appendices is a list of currently relevant patent literature surrounding the steam reforming process and the production of methanol from methane.

7.4.4 Summary

Methanex New Zealand Limited holds a variety of other patents on proprietary technology it has developed in order to maintain its New Zealand assets. It operates on a daily basis converting methane to methanol from a natural gas feedstock, so this part of the process should not require any new patent developments. The technology surrounding bioprocessing of organic waste to create biogas has existed for a number of years and is open to further development to improve system efficiencies. There are no current patents involving this specific application of the technology currently issued in New Zealand. It is therefore recommended that Methanex develop the specific application of this technology process and look into the possibility of patenting the procedure as it develops and improves the operation of each of its plants in the early stages of this new business venture. Furthermore, the technology will undergo changes and improvements so the opportunity for future patent application is great, providing a method to secure a mid-term competitive advantage.

8. Sustainability

A detailed analysis of the company's actions was undertaken to determine the sustainability of the venture. Further details are outlined in the appendix.

The three pillars of sustainability were used to analyse the impacts of the venture.

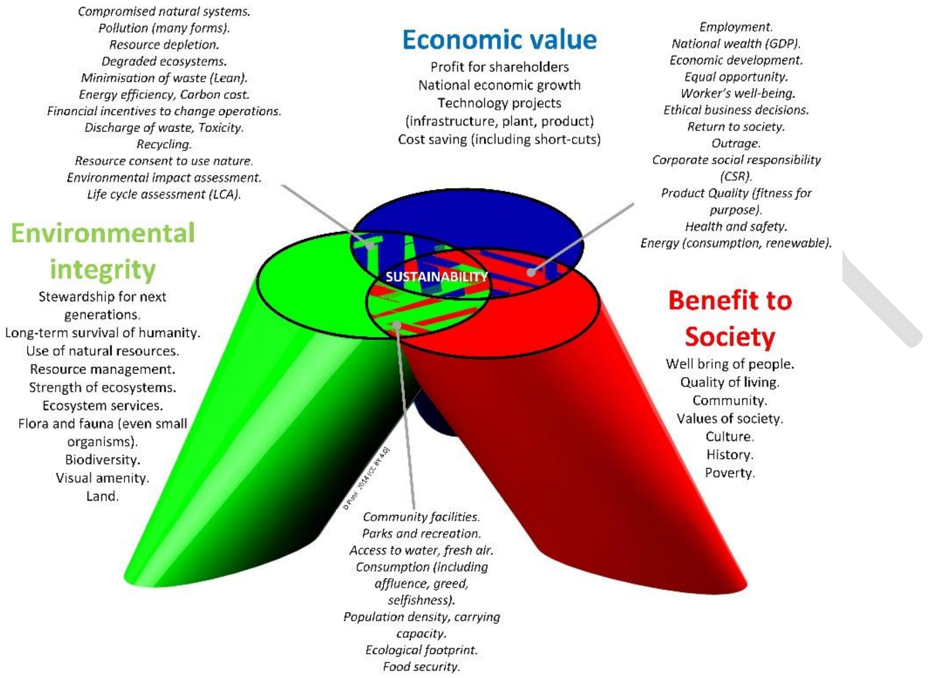

Figure 7: Three Spheres of Sustainability [2]

8.1 Economic Sustainability

Methanol is a very high value product used as a building block for a variety of everyday products and applications and is also used as a clean-burning alternative energy source. The large source of biogas available in New Zealand has the potential to be harnessed to create meaningful energy sources and products. The venture will add economic benefits to local farmers in the form of reduced fertiliser costs and potential access to government financial incentives to reduce greenhouse gas emissions. In addition, it will add value to the national economy through job creation in construction and management of the methanol plants and the production of high value methanol products.

8.2 Social Sustainability

The venture in methanol production from biogas has the potential to add great social value to the local community. The added economic value outlined above has an inherent flow on effect for social sustainability, as it has an impact at the local level. As jobs are brought to the local community and more labour is required, the social well-being of the immediate community will benefit as the economic sustainability of the regions increase.

8.3 Environmental Sustainability

There are a number of environmental benefits associated with the venture. Principally, the reduction in methane emissions is beneficial to all parties. Methane is over 20 times more harmful than carbon dioxide as a greenhouse gas. Another benefit is the reduction in effluent run-off and the reduced necessity for powerful nitrogen fertiliser usage leading to algal blooms that are responsible for severe pollution of New Zealand waterways. The reduction of odours is also another benefit for farm neighbours and communities. Methanol can be used as a sustainable fuel or as a component of environmentally friendly biofuel. By lowering society's dependence on traditional fossil fuels it is hoped that alternative fuel availability, such as methanol or its derivatives, will encourage the necessary shift in thinking to lead to true environmental sustainability.

9. Human Resources

The table below outlines the standard rate and the total amount of hours contributed to the project by each employee. Further details regarding human resources can be found in the appendix of the report.

Resource Name	Std. Rate	Total Hours	Cost Throughout project
Secretary	$40.00/hr	473.95	$18,958.05
Lead Project Engineer	$120.00/hr	7,389.95	$886,794.15
Administration assistant	$40.00/hr	560.00	$22,400.00
Project Engineer	$80.00/hr	8,009.83	$640,787.20
Methanex General Employee	$120.00/hr	112.00	$13,440.00
Economic Analysis	$65.00/hr	3,624.00	$235,560.00
Economic Analysis 2	$65.00/hr	3,680.00	$239,200.00
Human resource manager	$60.00/hr	519.81	$16,308.86
Methanol specialist	$120.00/hr	504.55	$60,545.59
PR Manager	$70.00/hr	14,424.27	$1,009,138.99
PR Manager 2	$70.00/hr	17,264.00	$1,207,920.00
Lawyer	$200.00/hr	1,439.45	$287,888.00
Marketing Manager	$60.00/hr	13,404.00	$803,760.00
Marketing Manager 2	$60.00/hr	17,264.00	$1,035,360.00
Contractors	$80.00/hr	168.00	$13,440.00
Civil Engineering team	$500.00/hr	776.00	$388,000.00
Head Civil Engineer	$150.00/hr	608.00	$91,200.00
Chemical Engineering team	$500.00/hr	7,352.00	$3,676,000.00
Head Chemical Engineer	$150.00/hr	6,064.00	$909,600.00
Mechanical Engineering team	$500.00/hr	168.00	$84,000.00
Head Mechanical Engineer	$150.00/hr	224.00	$33,600.00
Workshop technician	$100.00/hr	728.00	$72,800.00
R&D Engineer	$120.00/hr	8,448.00	$1,013,760.00
	Total		**$12,760,460.84**

10. Communication Plan

Identify stakeholders and grants

New Zealand based organisations with expertise in biogas and methanol production actively engaged in these industries are listed below.

Suppliers	
AECOM	Consulting engineers: civil, energy, environmental planning and industrial design
University of Canterbury	Research and consulting
Bioform	Consulting: agro-business
BECA	Consulting Engineers: civil, wastewater, mechanical, environmental planning and industrial design
Eastharbour	Consulting Engineers: energy planning
Greenlane/Flotech	Equipment Suppliers: biogas upgraders, compressors
NIWA	Research and consulting: small scale biogas systems for wastewater and farm waste treatment, advanced biogas utilisation, improved AD nutrient reuse
PGG Wrightson	Advisors and Suppliers: agro business
Ravensdown	Fertiliser suppliers and agro advisory
Methanex	New Zealand's only methanol production unit
Operators	
Christchurch City Council	Operators of landfills, wastewater treatment plants, co-digestion, solids drying, and biogas transfer network. New Zealand's first biogas tri-generation plant
Dunedin City Council	Operators of digesters and landfills
Fonterra	New Zealand's largest dairy cooperative Operators: wastewater digester and boilers
Hamilton City Council	Operators of digesters
Palmerston City Council	Operators of digesters and co-digesters
Transpacific Industries (NZ)	Operators of landfills Also hosting a pilot project – NZ's first biogas powered rubbish truck
Watercare Limited	Operators of digesters
Wellington City Council	Operators of landfills and sludge treatment plants
Landcorp Rangiora	Biogas CHP system based on dairy cow manure digestion in heated mixed digesters
Gas	
Contact energy	Gas suppliers and distributers
Genesis energy	Gas suppliers and distributers
Greymouth petroleum	Gas suppliers and distributers
Mercury energy	Gas suppliers and distributers
OnGas	Gas suppliers and distributers

[3]

Appendices

1. Introduction

1.1 General

The raw material used to produce biogas is called 'feedstock'. The feedstock (e.g. manure) is collected and held in tanks or ponds, the gas produced is captured, and this is used either as fuel in its own right (to heat buildings or power vehicles), or to drive a generator that provides electricity. Systems for extracting and using biogas on farms have been used for decades in Europe and North America. A biogas system may be as simple as fitting a cover to ponds, or as sophisticated as a fully automated off the-shelf system using tanks. A well-designed system offers other benefits: odour control, reduced contamination of groundwater and production of bio fertiliser.

Manure from the farm's 900 cows is collected on a concrete pad outside the milking sheds, and pumped into a tank digester. The gas produced is used to power a generator that provides around a third of the farm's energy requirements. There are environmental benefits to the biogas system also. The digestate that comes out of the tank is very low in pathogens compared to raw manure, and is ready for use on paddocks as an effective bio fertiliser. This comes on top of the reduction in carbon emissions from using up methane in the biogas.

1.2 Environmental

Methane has 20 times more greenhouse gas effect than carbon dioxide. The process of burning biogas for electricity generation and/or heat or to power an internal combustion engine converts methane into carbon dioxide, so this significantly reduces total greenhouse gas emissions.

By extracting methane out of waste and using it to produce heat and/or electricity the company can ensure that the waste will not degrade in an open environment therefore reducing direct methane atmospheric emissions. Moreover, the energy provided by the biogas is likely to displace fossil fuel which is the main contributor to greenhouse gas emissions.

Biogas energy is considered carbon neutral, since carbon emitted by its combustion comes from carbon fixed by plants (natural carbon cycle).

Despite popular belief, the amount of waste going in the digester is almost equal to the amount coming out. However the quality of the waste is altered for the better (less odour, better fertilizer, organic load reduced, less polluting).

Waste coming out of the digester can be separated (solid/liquid): the solid part can be composted and the liquid part can be used as liquid fertilizer or can be treated further and disposed.

2. System Architecture

2.1 Process of steam reformation of methane into methanol [4]

1. INTRODUCTION

Methanol demand in the global market is burgeoning with a 23% increase from 2010 to 2012 to 61 million tons and an expected increase to 137 million tons in 2022 [1]. However, its raw material: natural gas faces both supply limitation and volatility; as a non-renewable resource, natural gas is expected to deplete as early as 37 years depending on the level of conservativeness [2] while gas infrastructure in Europe is fragmented and inconsistent [3]. At the same time, environmental concerns for carbon emissions necessitate the integration of carbon capturing technologies. These usher a new age of sustainable design in this age-old process, and it will be reviewed in this report. A base case for the methanol synthesis was developed and optimized, followed by case studies on biogas substitution and alternative carbon capture opportunities.

2. PROCESS DESCRIPTION

For the base case, the methanol synthesis is generally split into steam reforming, methanol synthesis, hydrogen separation and methanol purification, which are described in this section.

Steam reforming: This is an overall endothermic reaction involving catalytic conversion of methane and steam into syngas at high temperatures above 800°C [4], medium pressures of 15-30 bar [5] and steam to carbon (S/C) ratio of 2 to 4 using nickel catalysts. Steam reforming is limited by equilibrium [6], and higher conversion is achieved by increasing temperature, lowering pressure and higher S/C ratio. It usually occurs in nickel catalyst-packed tubes located in the radiant section of a furnace.

Steam Reforming: $CH_4 + H_2O \leftrightarrow CO + 3H_2$ (ΔH_{25C} = 206kJ/mol) ---------------- (1)
Water Gas Shift: $CO + H_2O \leftrightarrow CO_2 + H_2$ (ΔH_{25C} = -41kJ/mol) ---------------- (2)

Methanol Synthesis: Syngas can be catalytically converted to methanol via an overall exothermic reaction at medium temperatures of 210-270°C and high pressures of 50-100 bar [7], over copper-alumina catalysts. The presence of the water-gas shift reaction necessitates the use of a modified stoichiometric ratio defined below, and it is typically in the range of 9-10 [4].

Methanol Synthesis: $CO + 2H_2 \leftrightarrow CH_3OH$ (ΔH_{25C} = -91kJ/mol) --------------- (3)
Modified Stoichiometric Ratio: $R = \frac{H_2 - CO_2}{CO + CO_2}$ --- (4)

Methanol synthesis reactors are designed to remove reaction heat via cooling service fluids such as unheated reactants or boiler feed water as well as feed quenching [8]. Isothermal cooling in shell and reactor tube setups was modeled under conditions known to approach equilibrium [4], and it can achieve higher conversions with lower temperatures, higher pressures and stoichiometric ratios.

Methanol Purification: Methanol synthesis products containing methanol and syngas are flashed to separate unconverted light ends and crude methanol. Crude methanol is distilled to separate remaining light-ends, methanol at 98%wt and water, in an atmospheric column with a partial condenser.

Hydrogen Separation: The flashed light-ends contain excess hydrogen; to avoid recycle accumulation, these must be purged for furnace fueling or purified for hydrogen credit via pressure swing adsorption, cryogenic distillation or membrane separation [9] with the latter being cheaper at the low recoveries and purities required [10]. For this, polyimide membranes are fabricated as hollow fiber tubes in a shell, and separation is achieved by partial pressure differences.

2

3. METHODOLOGY

The process was simulated using Aspen HYSYS v7.2, and individual units were designed to sufficient detail for costing based on the module factor approach [11]. Expected revenue from methanol (€0.413/kg [12]) and hydrogen (€8.04/kg [13]) sales was factored in for a plant-wide optimization. The methodology for design and costing for each unit for the optimization is elaborated below.

3.1 Steam Reforming Section Optimization

This section focuses on the reformer furnace with the reaction modeled to reach equilibrium and the costing based on energy used. This is independent of downstream synthesis and is optimized separately. The variables affecting this section are the pressure, furnace temperatures (i.e., pre-heat and outlet temperatures) and S/C ratio; these affect costs of individual sections/units, and their expected effect on profit is shown in Table 1.

Table 1: Expected effect of increase in design variables on profit due to costs of individual sections/units

Design Variable	Energy Recovery from Natural Gas	Convection Section	Radiant Section	Compression	Conversion
Pressure	↓	Uncertain	Uncertain	↓	↓
Pre-heat Temperature	NA	↓	↑	Uncertain	↑
Outlet Temperature	NA	NA	↓	Uncertain	↑
S/C Ratio	NA	↓	↓	↓	↑

Energy Recovery: Natural gas is expected to be delivered at 75 bar within European pipelines [3] and must be expanded via a valve or turbine for energy recovery to the desired pressure; the latter can be achieved with radial gas turbines at 75-88% efficiency [14] together with a minimum motor generator efficiency of 95% mandated by EU Directive 640/2009 [15]. The turbine was priced based on energy recovery rate and capital costs.

Steam Reformer Furnace: Natural gas is mixed with steam and preheated in the convection section before reaction in the radiant section. The duties are summed, and used for furnace capital and energy costs. Catalyst life is assumed to be within industrial norm, and is priced based on USD$0.55 per kilo mole of natural gas processed [16]. A 95% approach to equilibrium was found to best match industrial data from [17], and this was used in the reactor simulations

Water Let-Down Vessel: Excess steam is condensed and removed from the reformer products, in a knock-out vessel to ensure dryness for the compression train. The design is based on the water throughput to allow for 7.5 min of residence time, and the vessel volume is used for capital costing. The condensate is pumped up to process pressure and reheated as recycle steam to the reformer.

Make-up Compressor: A separate compression train for syngas products (i.e., fresh feed) is designed because it has less variability than the recycle compressor and so requires less capacity allowance. For the discharge pressure of 50-100 bar and required flow of about 0.410 m^3/s, reciprocating compressors are suitable and are used for costing at 75% efficiency. To avoid adiabatic temperature rise beyond the maximum temperature of 480 K [14], two-stage compression is used with inter-stage cooling. This cooler is designed using heat transfer area obtained using typical overall heat transfer coefficients and log mean temperature difference for cooling water service [18].

2.2 Process Flow Diagram – methane to methanol

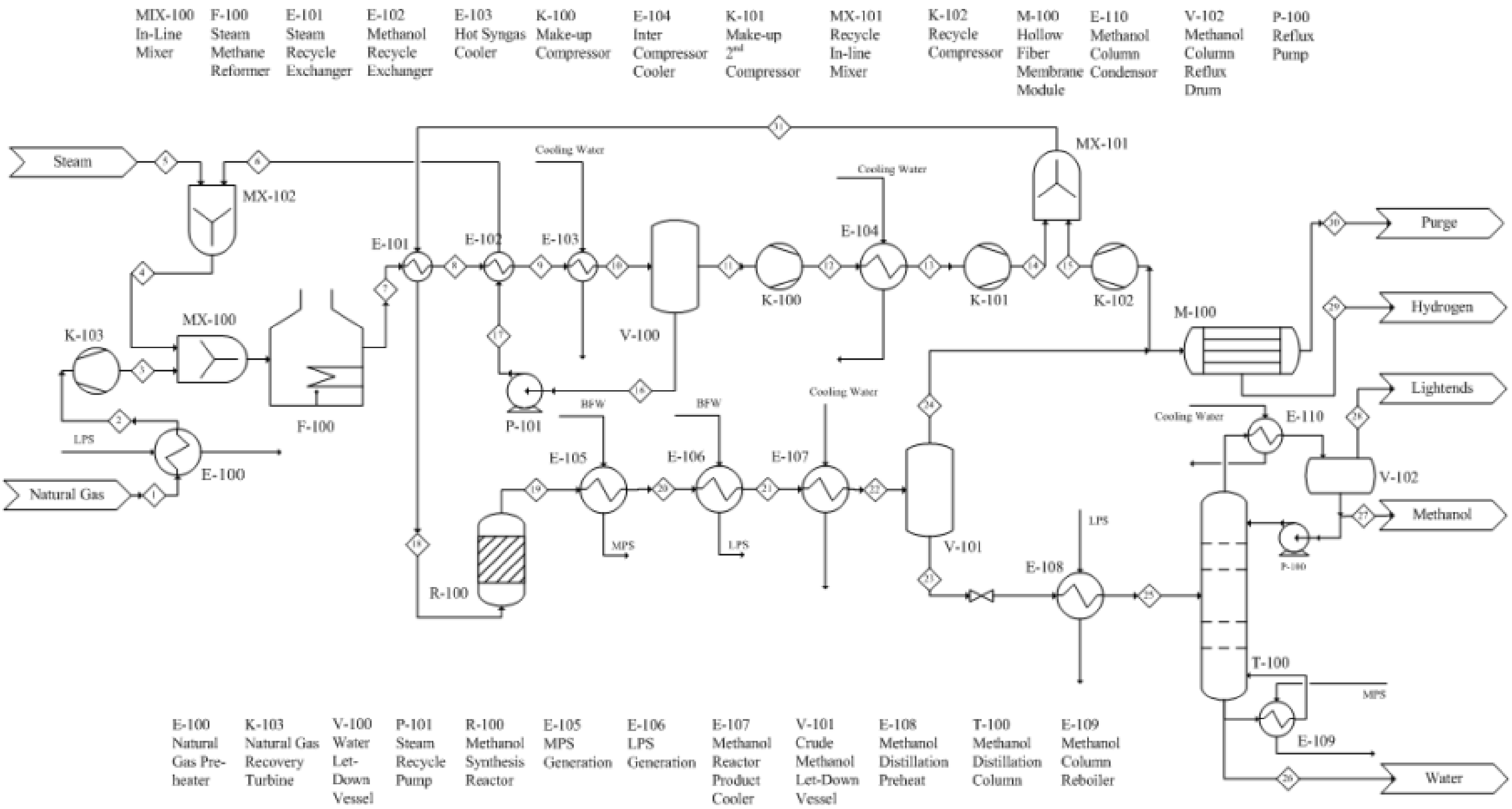

Figure 81: Process flow diagram of steam reformation of methane into methanol

[4]

3. Risk Assessment

3.1 Risk register

Reference	Risk	Recommended action / Treatment	Consequence	Likelihood	Consequence
Political					
1	Implementing methane gas systems would be a good thing for the environment which would appeal to many New Zealanders	1. Pass on information to general public of the benefits of these systems to the environment by running informative advertising across many forms of media 2. Appeal to Green minded political parties and MPs to inform their electorate of the benefits to the environment	Huge gain	Almost certain	High Opportunity
2	Potentially lead to shutdown of Huntly PowerStation which would lead to loss in jobs and money for local region, this will displease the people of Huntley	1.Stress that replacement jobs will be created by the project 2. Base operations In Huntly.	Negligible Loss	Likely	Low Risk Loss
3	Able to apply for government funding, which would help project finances significantly	1. Organise a convincing campaign to get government funding 2.Apply for largest sum of money	Huge Gain	Likely	High Opportunity
Economical					
4	Save dairy farmers money on fertiliser bills	1.Ensure that fertiliser demand of farmers is met by system	Major Gain	Likely	High Opportunity
5	Create Jobs in manufacturing and servicing industries	1.Strive to manufacture components within New Zealand 2.Work with existing New Zealand farm service providers	Moderate gain	Possible	Medium Opportunity
6	Makes New Zealand product more desirable internationally	1.Reasearch how green image effects overseas sales 2.Make these benefits known to potential customers	Moderate gain	Likely	Medium Opportunity
7	Opportunity for export of New Zealand methane technology	1.Search for similar gap in market outside of New Zealand 2.Inform possible international clients of benefits and New Zealand testing	Huge Gain	Possible	High Opportunity
8	Run out of funding before product is able to be mass marketed	1.Manage funds and plan expenditure 2.Have back up funds available 3.Constantly look for investors	Severe Loss	Unlikely	High Risk Loss
9	Country enters economic hardship before product is mass marketed	1. Secure funds as soon as possible after they are promised 2.Look at investors from over seas	Major Loss	Rare	High Risk Loss
10	Obtain funding from overseas governments who are also interested in implementing the technology	1.Search for countries with similar industries 2.Inform them of the benefits	Moderate gain	likely	Medium Opportunity
11	Make a lot of money if technology is successfully applied on a large scale	1. Ensure that once benefits have been quantified that this information is widely available 2.Ensure that ability to manufacture is able to keep up with demand	Huge gain	likely	High Opportunity
12	Lack of funding to hire competent people	1.Secure funding early and set aside a sufficient amount to hire people with enough expertise	Major Loss	Rare	High Risk Loss
13	Free advertising opportunity's from interested media	1.Send information packs to all forms of local and international media when a major target has been reached	Huge Gain	Possible	High Opportunity
14	Required technology already exists , so R&D costs are about making technology more viable on a smaller scale	1.Reasearch existing patents in related areas	Moderate gain	Possible	Medium Opportunity
15	Market competitor releases another product with similar benefits	1.Ensure that security procedures are in place to prevent espionage 2.Reasearch market to make sure that competitors are not able to do so	Severe Loss	Unlikely	High Risk Loss

Social					
16	Severe Injury or death due to misuse of technology	1.Ensure that systems comply with relevant standards 2.Ensure that customers are trained and well informed on how to safely operate systems	Severe Loss	Very Rare	High Risk Loss
17	New Zealand population get on board with the idea	1.Capitlise on interest of public and hold meetings and spread information	Major gain	Possible	Medium Opportunity
18	Project showcases New Zealand as a positive example to the rest of the world, which could lead to more business	1.Have projections on benefits for other countries with possible markets ready for when possible overseas customers are interested	Major gain	Likely	High Opportunity
19	Project causes job reduction for small towns near Huntly PowerStation	1 Where possible manufacture components in towns effected by closer of power stations	Minor loss	likely	Medium Risk Loss
20	Project creates manufacturing and servicing jobs	1.Ensure manufacturing jobs stay in New Zealand	Moderate gain	Almost certain	Medium Opportunity
21	Vandalism of instruments from members of public whose jobs are negatively effected	1.Ensure that test system has high level of security 2.Work with local communities to address grievances	Minor loss	Rare	Low Risk Loss
22	Cements New Zealand's image of being an innovative nation	1. Inform government of likely benefits 2.Captilise on any advertising government offer	Moderate gain	Likely	Medium Opportunity
23	Ascetics of systems could be viewed negatively	1.Consult an audience of people who live near where systems will be put into place	Minor loss	possible	Medium Risk Loss
Technological					
24	Early system gets damaged or misused	1.Have spare parts manufactured 2.Educate operators of early devise on how to operate properly	Moderate loss	possible	High Risk Loss
25	System could require high levels of Maintenance	1. Design systems with ease of maintenance in mind	Minor loss	likely	Medium Risk Loss
26	Problems manufacturing large numbers in New Zealand	1. Plan for large manufacturing order 2.Have back up manufacturing facilities	Moderate loss	Possible	High Risk Loss
27	Failing of components in prototype system	1.Test each component before testing the whole system 2.Have spare parts ready to replace broken ones	Minor loss	Possible	Medium Risk Loss
28	May find possible improvements to the system during prototype system testing	1.Test porotype system and be open to changes in design	Moderate gain	Likely	Medium Opportunity
29	Some possible locations may be highly inaccessible	1.Design components with ease of transport in mind 2.Design components so that they can be transferred up gravel roads	Moderate loss	Rare	Medium Risk Loss
30	Difficulty in extracting all of methane from manure	1.Set aside a larger proportion of R&D budget to solve the issue	Major loss	likely	High Risk Loss
31	Unable to collect manure efficiently	1.Set aside a larger proportion of R&D budget to solve the issue	Major loss	possible	High Risk Loss
Environmental					
32	Reduce reliance on fossil fuel generated power in the North Island	1.Keep possible clients informed on what is being achieved	Huge gain	likely	High Opportunity
33	Reduce harmful effects of methane from cow manure	1.Reasearch the benefits of burning methane rather than releasing it into atmosphere	Moderate gain	Almost Certain	Medium Opportunity
34	Improve New Zealand’s Waterways by reducing amount of manure	1. Inform clients about harmful effects of manure in waterways and benefits of using it to burn instead	Huge gain	Possible	High Opportunity
35	Carbon footprint of manufacturing instruments outweighs benefits	1. Try to produce components in south Auckland/Waikato to reduce transportation footprint. 2.Try to use materials available as locally as possible	Moderate loss	Very Rare	Medium Risk Loss
Legal					
36	Patent may have already been submitted that will restrict use of certain components	1.Research patients before committing major time and money	Severe Loss	Rare	High Risk Loss
37	Planning consent denied for systems	1.Researrch planning rules and put time and m9oney aside to make sure that submissions are of a high standard	Severe Loss	Unlikely	High Risk Loss
38	Industrial espionage from employees could set back project	1.Invest in security of physical and virtual IP	Severe loss	Very Rare	High Risk Loss

3.2 Liability risks

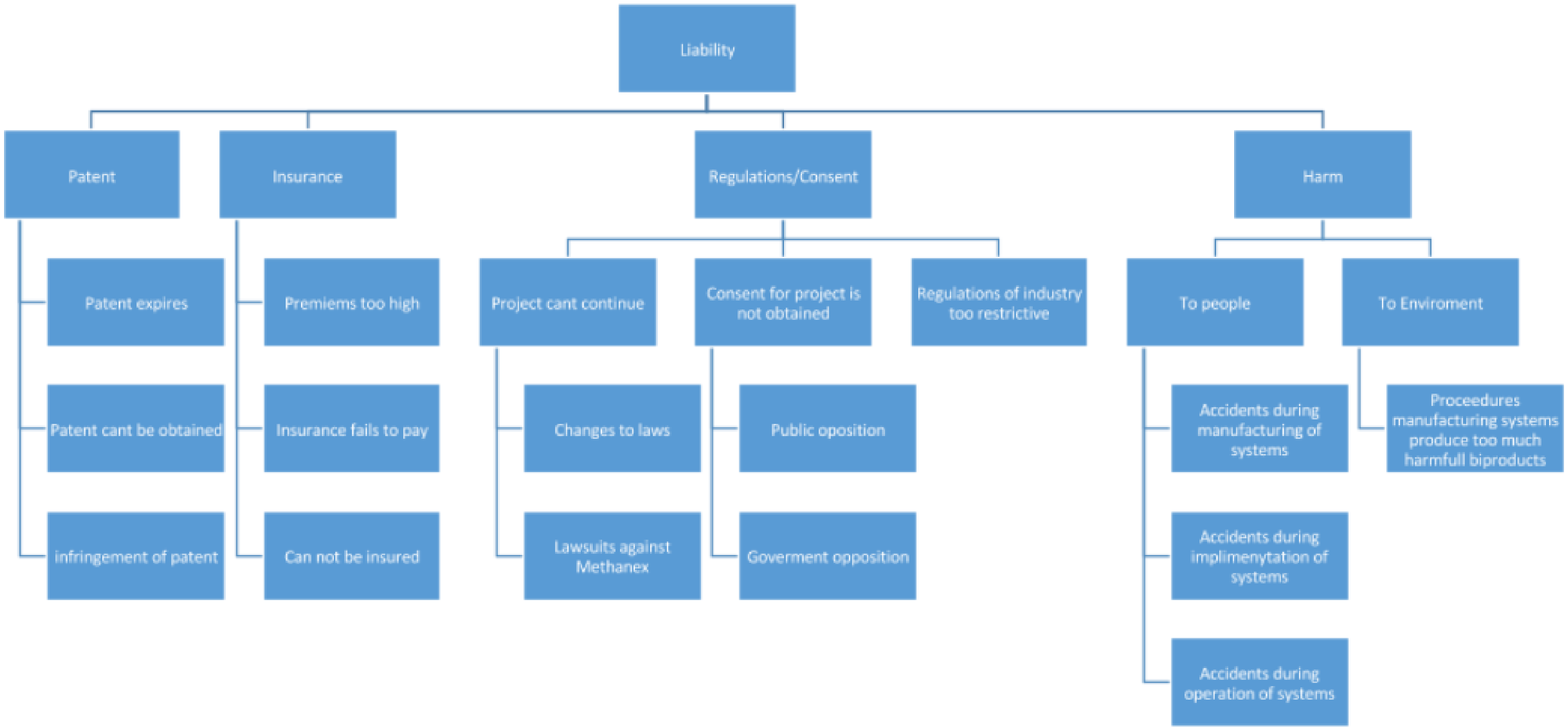

Figure 19: Liability fault tree analysis

3.3 Functional Failure risks

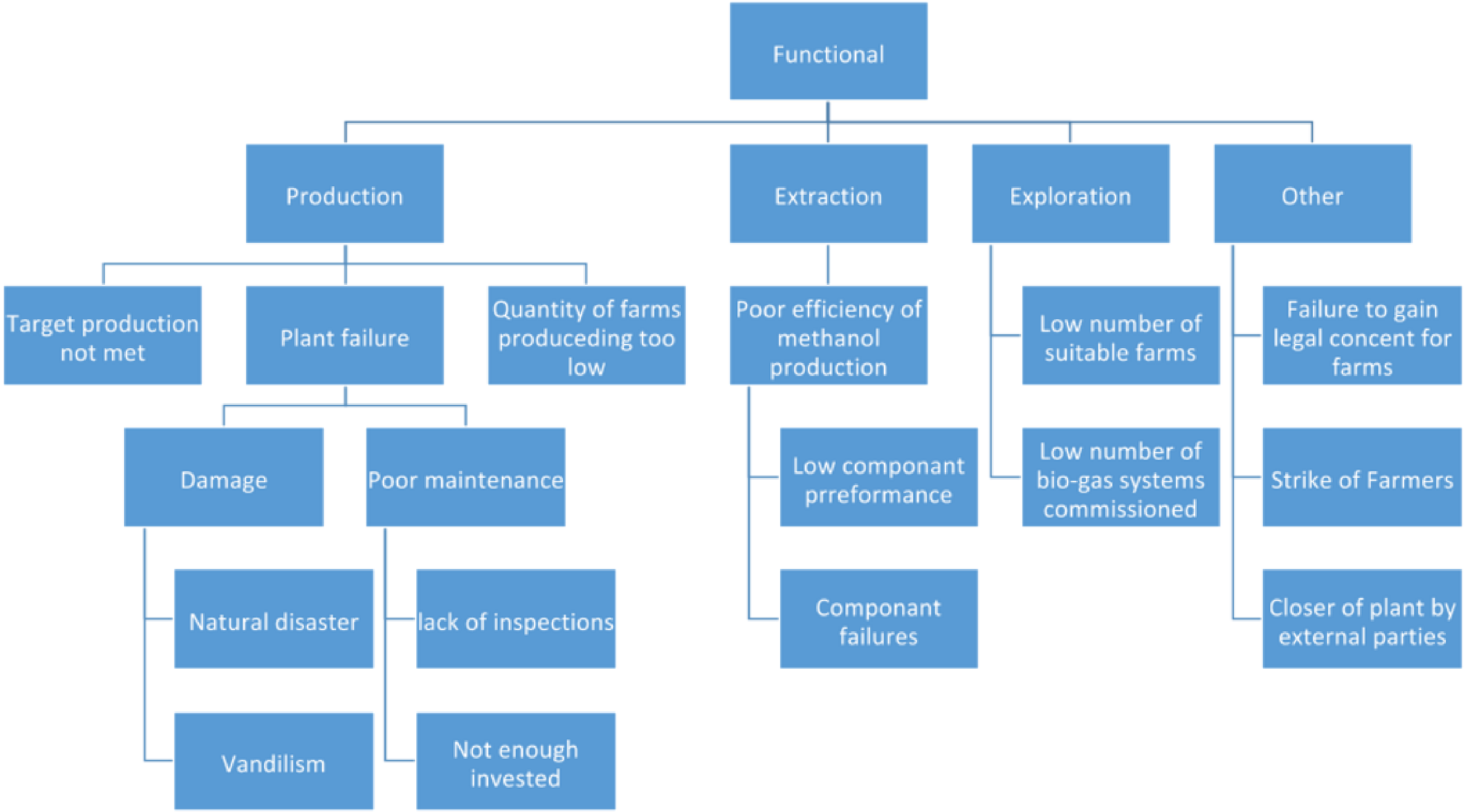

Figure 110: Functional Failure Fault Tree Analysis

3.4 Health and safety risks

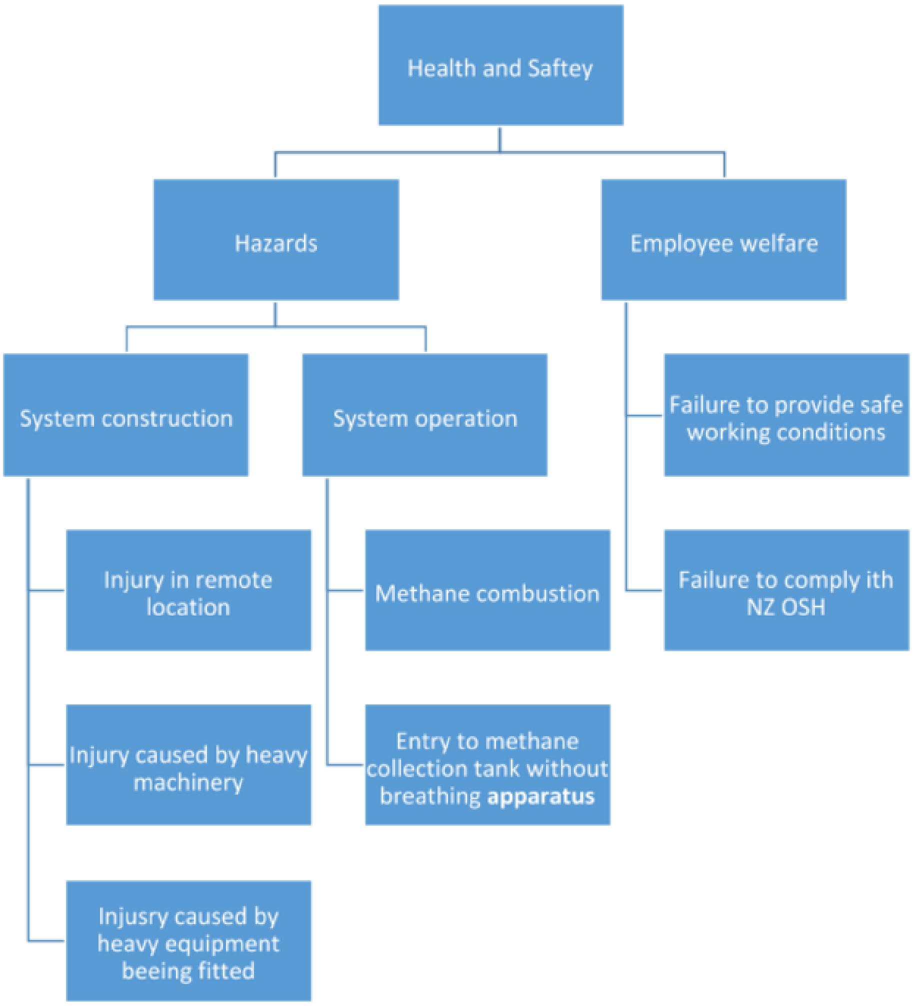

Figure 111: Health and Safety Fault Tree Analysis

4. Financial analysis

4.1 Cash flow analyses

Cash flow analyses were conducted for each of the scenarios for optimistic, expected and pessimistic future predictions.

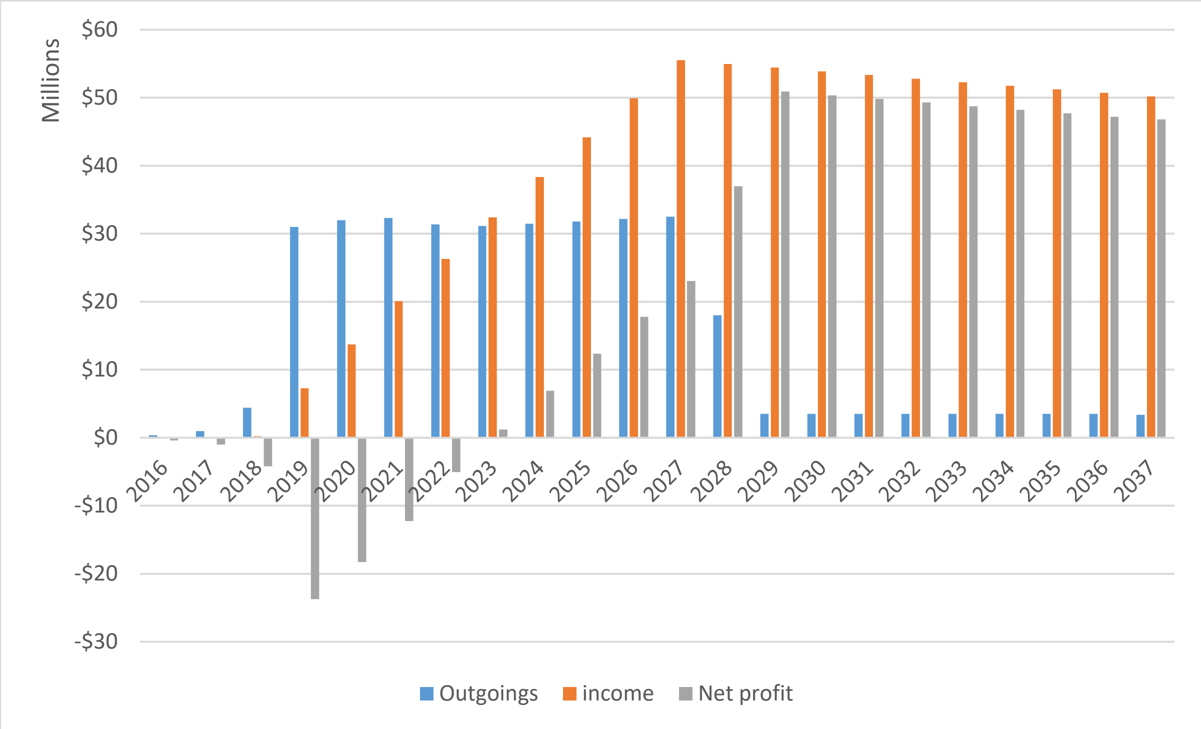

Figure 112: Cash flow for Optimistic Prediction

Figure 113: Cash flow for Expected Case

Figure 114: Cash flow for Pessimistic Case

4.2 Equipment costs

Table 6: Equipment cost for Bio processor

Item	Cost
Total pipe cost (10km)	$8,505
Installation cost	$8,505
Bio-processor equipment	**$96,000**
Foundation	$12,040
Digester	$22,152
Roof	$7,223
Gas pump	$3,371
Boiler	$2,889
Hydra-ram manure pump	$23,600
Supplies	$15,900
100 m^3 methanol storage tanks	$5,000
Methanol Plant set-up	$50,000

4.3 Potential cost reductions to the farmer

Table 7: Cost of fertiliser [2]

Item	Cost
Fertiliser cost saved (Urea)	$5,275 per annum

4.4 Unconsidered costs

Other costs that have not been considered within the cash flow analysis of the company include the cost of land that the plants are situated on. Land hire costs have also not been considered for the case when farmers refuse to provide space for bio-processors on their own land for free. If the venture is still deemed to be unattractive to the farmer then a small percentage of the annual revenue of the plant will have to be attributed to paying the farmer for the use of their land.

5. Route to market

5.1 Patent literature

1. **Oxidation of methane to methanol**

US 4982023 A

ABSTRACT

A marked improvement in yield, in selectivity or in both is obtained in the synthesis of methanol by the homogeneous direct partial oxidation of natural gas or other source of methane when the reactor space is filled with inert, refractory inorganic particles.

Status: Lapsed

Assignee: Mobil Oil Corporation

2. **Direct conversion of natural gas to methanol by controlled oxidation**

US 4618732 A

ABSTRACT

A process of directly converting natural gas to methanol employs controlled oxidation. The reaction takes place in an inert reactor, i.e. one having internal surfaces which do not affect the reaction, in the absence of a catalyst. The natural gas is intimately mixed with air or oxygen prior to introduction of the mixed gases into the reactor. Reaction takes place at an elevated temperature of 300° to 500° C. and at an elevated pressure of 10 to 100 atmospheres. The percentage of oxygen in the mixture of reactant gases is kept below 20% by volume and is preferably 2 to 10% by volume. Apparatus for carrying out the method is also provided.

Status: Lapsed

Assignee: Gesser Hyman D, Hunter Norman R,Lawrence Morton

3. **Method and system for methanol production**

US 7910787 B2

ABSTRACT

An apparatus and method of producing methanol includes reacting a heated hydrocarbon-containing gas and an oxygen-containing gas in a reactor; to provide a product stream comprising methanol; and transferring heat from the product stream to the hydrocarbon-containing gas to heat the hydrocarbon containing gas. After removing methanol and CO_2 from the product stream, unprocessed hydrocarbons are mixed with the hydrocarbon containing gas for reprocessing through the reactor. Reactor byproducts are injected into the ground to increase the output of a hydrocarbon producing well.

Status: Active

Assignee: Gas Technologies Llc

4. **Method and apparatus for producing methanol**

US 8293186 B2

ABSTRACT

An apparatus and method of producing methanol includes reacting a heated hydrocarbon-containing gas and an oxygen-containing gas in a reactor; to provide a product stream comprising methanol; and transferring heat from the product stream to the hydrocarbon-containing gas to heat the hydrocarbon containing gas. After removing methanol and CO_2 from the product stream, unprocessed hydrocarbons are mixed with the hydrocarbon containing gas for reprocessing through the reactor.

Status: Active

Assignee: Gas Technologies Llc

5. **Hybrid system for Gasification of Biomass and conversion to synthesis gas suitable for fuel synthesis, with 3 potential applications**

US 20070100003 A1

ABSTRACT

Technical challenges of biomass-to-fuels conversion prompted the development of this hybrid system for biomass gasification. In this device, the matter is first pyrolyzed and the resulting vapors are drawn off and run through the char and tar in the second stage with the process steam in a supercritical steam gasification. The resulting gases are then purified by use of an amine wash scrubber. An adiabatic pre-reformer is then employed to break down aromatic compounds that most likely exist in the gas even after steam gasification. This gas is then fed to the main steam reformer, and afterwards the gas is cooled to suitable reaction temperatures for fuel synthesis. With a ratio H/C of 2.0, the gas is suitable for Fischer-Tropsch fuel synthesis, methanol synthesis, or production of hydrogen and carbon dioxide by a water-gas shift.

Status: Active

Assignee: Holley James L, Harris Aubrey L

The following patented technology has the potential to alter and improve the process of producing methanol from methane and could be worthwhile for Methanex to investigate and potentially invest in a license to use the technology.

6. **Anhydrous conversion of methane and other light alkanes into methanol and other derivatives, using radical pathways and chain reactions with minimal waste products**

WO 2004041399 A2

ABSTRACT

Reagents and methods with low thermodynamic barriers can convert lower alkanes such as methane into methanol or other derivatives. One system uses a small quantity of a non-salt radical initiator such as Marshall's acid, a di-acid peroxide that can be split into two radicals. These radicals will remove hydrogens from methane, to generate methyl radicals. Sulfur trioxide is added, and methyl radicals combine with it to form methylsulfonate radicals. Methane is added, and the methylsulfonate radicals will remove hydrogens from it, to form stable methanesulfonic acid (MSA) while creating new methyl radicals to sustain the chain reaction. MSA that is removed can be sold or used, or it can be split into methanol (which can be used on site, or shipped as a liquid) and sulfur dioxide (which can be oxidized to sulfur trioxide and returned to the reactor). This anhydrous system creates no salts and minimal waste. An alternate system uses a bi-functional reagent with electrophilic and nucleophilic domains (such as a bromate-sulfate compound) to create coordinated proton and electron shifts in methane, using symphoric and anchimeric effects to create transitional intermediates with low energy barriers, allowing selective formation of intermediates that can be cracked to release methanol. Either system can improve the selectivity and yield of methanol from methane.

Status: Active

Assignee: Alan K. Richards

7. **Tube Monitor and Process Measurement and Control in or for a Reformer**

US 20140105243 A1

ABSTRACT

The invention relates to methods and apparatus of measuring real time temperature conditions within a reformer. The data is then used for process control optimisation, overheat protection, and improved creep damage and fatigue life prediction.

Status: Active

Assignee: Peter Campbell Tait

Owner name: METHANEX NEW ZEALAND LIMITED, NEW ZEALAND

5.2 Notes for inventors and information for patent licensing in New Zealand

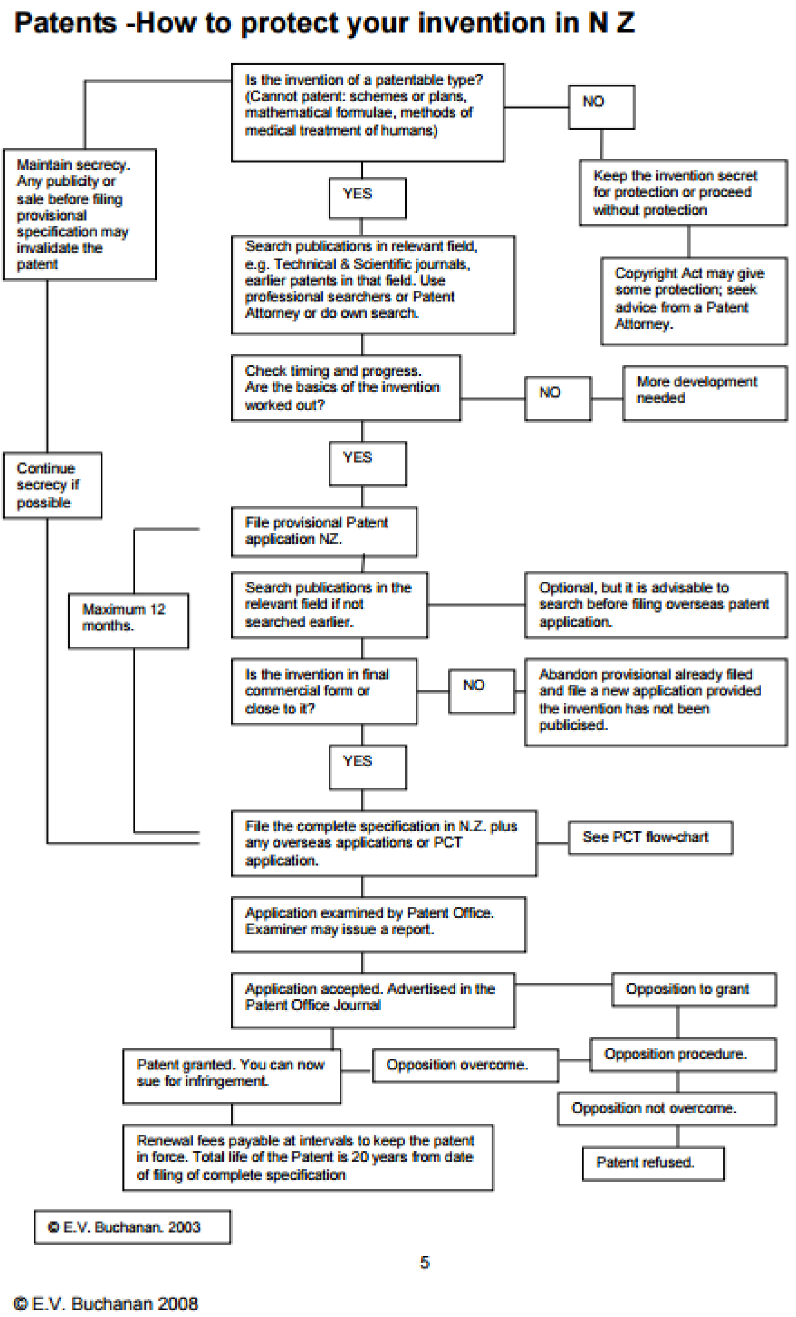

Figure 18: IP Protection routes [3]

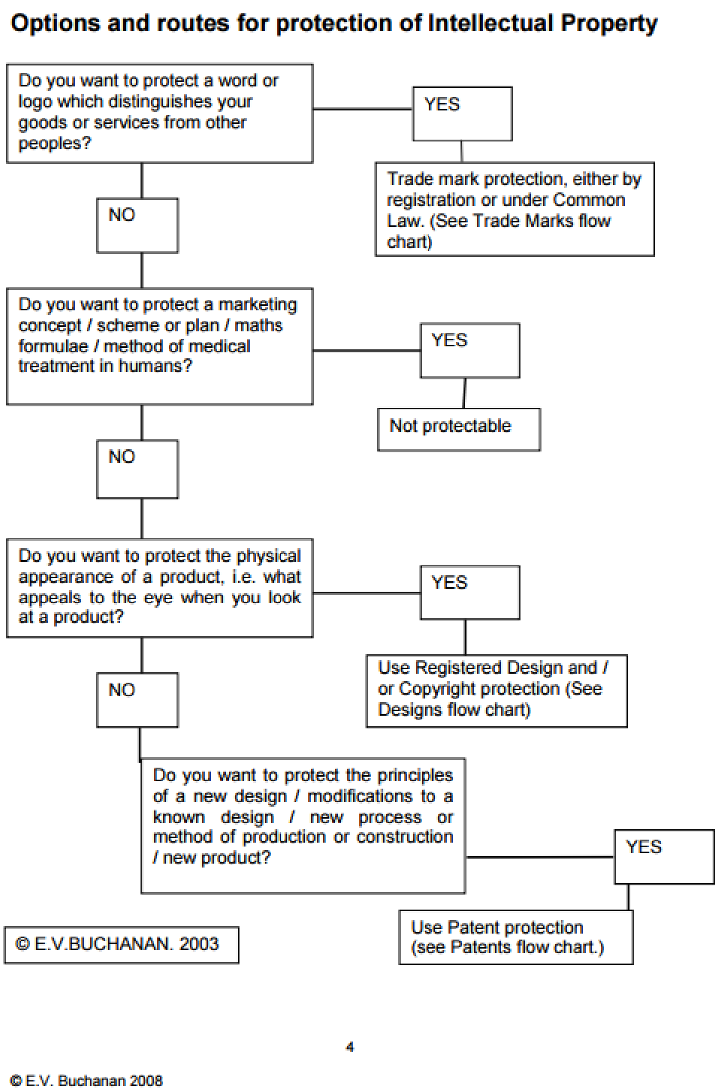

Figure 19: IP Protection routes [3]

6. Sustainability

Environmental Sustainability

6.1 Biogas motivation drivers

Farm Wastes

Media coverage of pollution associated with animal waste on farms is increasing but rarely positive. Anaerobic digestion is a tool enabling better farm waste management on dairy farms. It offers a significant advantage in being able to minimise odours, make nutrients (nitrogen) contained in farm wastes more plant available, and allow for better timing of effluent land application. Biogas recovery from farm wastes remains one of the very few practical and economical ways of reducing agricultural greenhouse emissions.

Balance of trade

Petroleum is New Zealand's single biggest import category and is likely to increase in future years. Petroleum imports use up almost all export earnings made by the dairy sector. Every small step that helps to reduce our dependence on imported petroleum is therefore very valuable for addressing our biggest economic problem – the current account deficit. Biogas transport fuel is the most efficient and effective transport biofuel available today and could help to substitute a meaningful amount of our petroleum imports and current account deficit. The use of methanol as a biofuel is outside the scope of this report, however there is a large amount of research and testing being conducted in this field for the use of methanol as a low emission alternative fuel source in cars, buses, aircraft and shipping.

Air Quality

Biogas and methanol have the potential to be used in a number of situations to reduce emissions to air and improve local air quality. An example is the use of Dimethyl Ether, a methanol derivative that is being used in public buses as a clean-burning substitute for diesel fuel, or methanol as a marine fuel to help meet the shipping industry's increasingly stringent emission regulations and improve global air and water quality.

Nutrient recycling and better waste management

World phosphorus supplies are becoming increasingly scarce and less available, while the production of nitrogen fertilizers is an energy intensive process. Returning both P and N contained in digested originating from wastes that alternatively would have ended up in a landfill or waterway to agricultural land can therefore help to enhance our national phosphorus supply security, and preserve finite natural resources.

[5]

7. Human Resources

7.1 Company structure

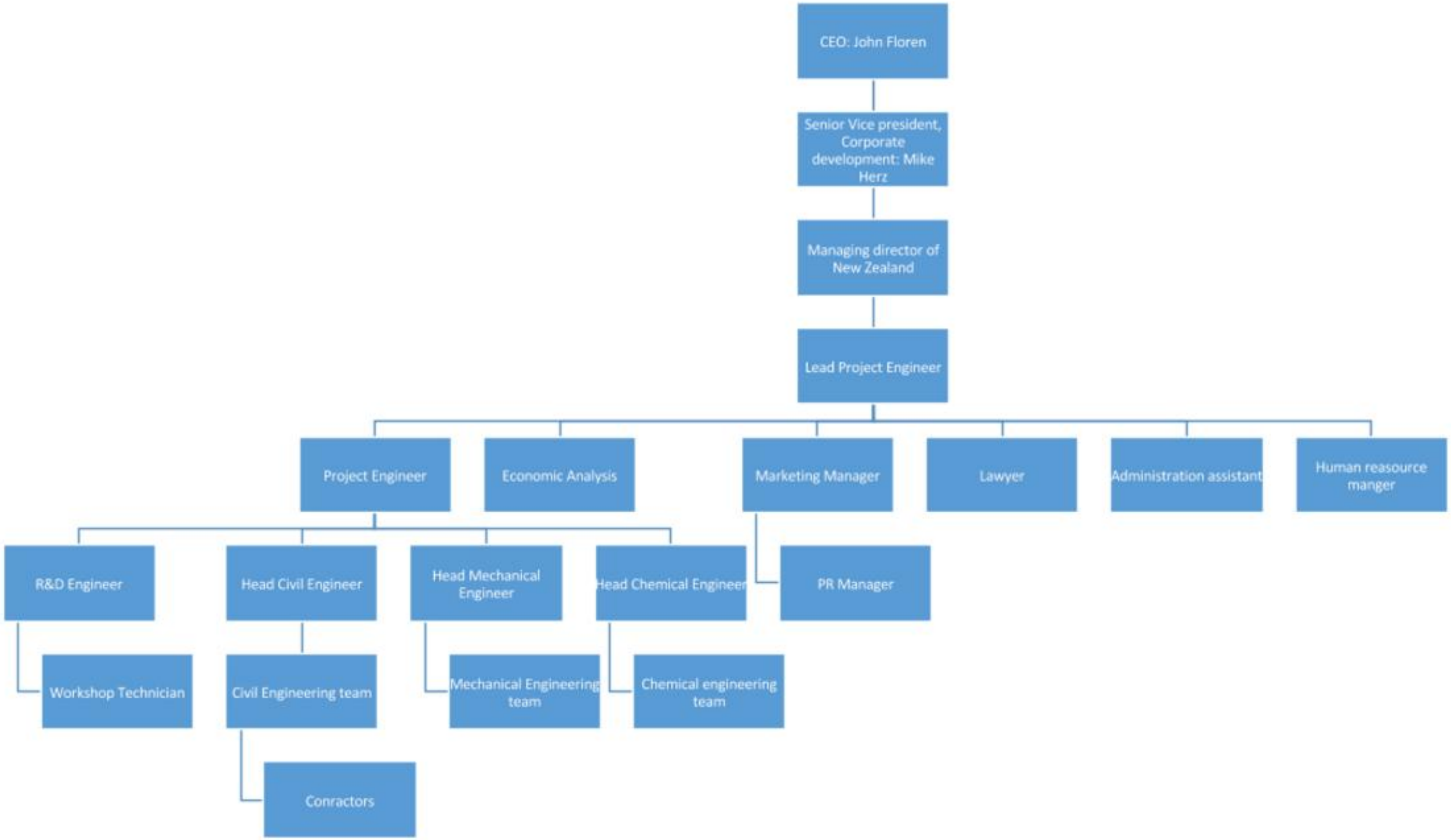

Figure 20: Human Resources Hierarchy

7.2 Job Categories and skill sets

Lead Project Engineer

A lead project engineer's role is to act as the head of the engineering team working on the project. The lead project engineer takes on a general managing role and works closely with leaders from other departments

Project Engineer

General engineering role acts as a bridge between different engineering roles, works on jobs which Lead project engineer is either too busy to do or over qualified

Human Resource Manager

Responsible for all job recruitment, must work well with other team leaders and attract staff with the relevant high level of skills

Methanol Specialist

Takes on a technical advisory role throughout the project and helps sell the project to would be investors and clients.

Lawyer

Responsible for all contractual and legal matters, works with the lead project engineer to ensure that the project obeys all relevant laws. Also helps submit plans for government grants if the project qualifies for them.

Mechanical Engineer

Responsible for installing and checking components of system, Responsible for maintaining scheduling

Electrical Engineers

Responsible for installing electrical components in the system. Will implement and develop user systems and interfaces

Chemical Process Engineers

Responsible for ensuring that all the system components are connected properly and the system as a whole preforms the job it's intended to do.

Civil Engineers

Responsible for planning and overseeing the building of the plant as well as designing any infrastructure that needs to be put in place (foundations etc.)

Marketing Manager

Responsible for designing and implementing a marketing strategy, will work closers with PR manager and economic analysis.

Secretary

During periods of high work volume it will be the secretary's job to assist the Lead project engineer, HR and PR manger with administration work.

Methanol Company Employee

General Project worker, duties include helping PR and HR managers with work.

Economic Analysis

Responsible for keeping up to date with market affairs and providing economical information to project leaders so they can make informed business decisions

Public Relations Manager

Responsible for any interaction with people from outside the company, whose main goal is to ensure good public, investor and government opinion about the project and company.

Contractors

Responsible for putting together the infrastructure of each system such as laying pipes or foundations.

Research and Design Engineer

Works in R&D department of the project, primary role is to improve components or processes to make them more efficient or cost effective

Workshop Technician

Builds and designs specific components and tools required for prototype before they can be mass produced

7.3 Full-time equivalent employee breakdown

Highlighted in Blue are the employees that have worked enough hours to be classed as full time workers. Full time workers are classed as people that work at least 40 hour weeks 48 weeks of the year (1920hrs). Highlighted in yellow are workers that have not reached that limit. Just because this limit has been reached it doesn't mean that they cannot be hired full time. Employees that are close to the 1920hr freehold (PR Manager, 2019) could be considered for full time hire as it would allow them to focus solely on this project throughout the year and allow for lee way should certain tasks take longer than originally thought.

Table 8: Full time equivalent breakdown

	Hours Worked											
Resource Name	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Secretary		473.95										
Lead Project Engineer	436.80	873.15	240.00	1,208.00	2,096.00	2,088.00	448.00					
Administration assistant	504.00	56.00										
Project Engineer	448.00	963.60	745.03	1,221.20	2,096.00	2,088.00	448.00					
Methanex General employee team	112.00											
Economical Analysis	328.00	1,168.00	2,088.00	40.00								
Economical Analysis 2	328.00	1,224.00	2,088.00	40.00								
Human resource Manager	332.48	187.33										
Methanol specialist		504.55										
PR Manager	464.00	652.27	352.00	1,528.00	2,096.00	2,088.00	2,088.00	1,304.00	1,048.00	1,044.00	1,044.00	716.00
PR Manager 2				1,208.00	2,096.00	2,088.00	2,088.00	2,080.00	2,096.00	2,088.00	2,088.00	1,432.00
Lawyer	242.88	844.57	352.00									
Marketing Manager		208.00	240.00	1,528.00	2,096.00	2,088.00	2,088.00	1,304.00	1,048.00	1,044.00	1,044.00	716.00
Marketing Manager 2				1,208.00	2,096.00	2,088.00	2,088.00	2,080.00	2,096.00	2,088.00	2,088.00	1,432.00
Contractors			168.00									
Civil Engineering team	224.00	384.00	168.00									
Head Civil Engineer		384.00	224.00									
Chemical Engineering team			952.00	1,768.00	2,096.00	2,088.00	448.00					
Head Chemical Engineer			224.00	1,208.00	2,096.00	2,088.00	448.00					
Mechanical Engineering team			168.00									
Head Mechanical Engineer			224.00									
Workshop technician		480.00	248.00									
R&D Engineer		480.00	2088.00	1248.00	2096.00	2088.00	448.00					

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