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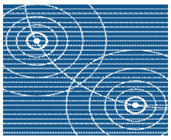

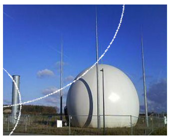

Biogas from Kiwifruit Waste

Zespri

15 April 2008

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Prepared for

Zespri

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Executive Summary

Zespri has been looking into ways of turning kiwifruit waste into something more valuable than animal fodder. The **objectives** of turning the waste into biogas are:

a) a reduction of post harvest costs and
b) improved market access in countries with potential concerns about the carbon footprint of kiwifruit from New Zealand.

Biogas digesters have become symbols for renewable energy on the European markets and Zespri is interested in knowing whether this technology could be introduced to New Zealand for demonstrating its commitment to **innovation** and the **environment**.

The short answer is the following:

- kiwifruit is rich in energy, similar to grapes or other fruit and is principally well suited for anaerobic digestion;
- for optimum biogas production, the substrate should ideally be pH neutral, and the lightly acidic kiwifruit waste would benefit from being mixed with other, more alkaline co-substrates;
- as the pack house operation is seasonal, an anaerobic digester plant solely fed by kiwifruit waste would only run for six to eight month in a year and would economically benefit from co-processing of other substrates, such as meat waste or communal waste, during the rest of the year;
- a biogas plant using kiwifruit and other substrates could either be located at one of the pack houses in the Bay of Plenty or at the site of another industry with high energy demand and organic waste, e.g. at the Affco meat processing plant in Te Puke;
- in a well managed co-digestion process, the energy produced from kiwifruit waste would have a higher value than that currently achieved from feeding the produce to cows, however, the value is still low compared with the value of exported kiwifruit;
- with regard to its potential impact on the carbon footprint, kiwifruit production is labour and energy intensive, and the energy consumed for production, processing, packing, transport and distribution **exceeds** the energy content of the fruit brought to market, and even more so, of the fruit waste, which is 16 - 18% of the entire production;
- revenue streams from the biogas production include the sale of energy and fertilizer, the reduction of waste that might incur environmental costs and, potentially, carbon credits;
- the positive, green image value could considerably enhance the project economics, if the message was communicated well to Zespri’s overseas markets.

We therefore recommend that Zespri undertake the **following, further project steps**:

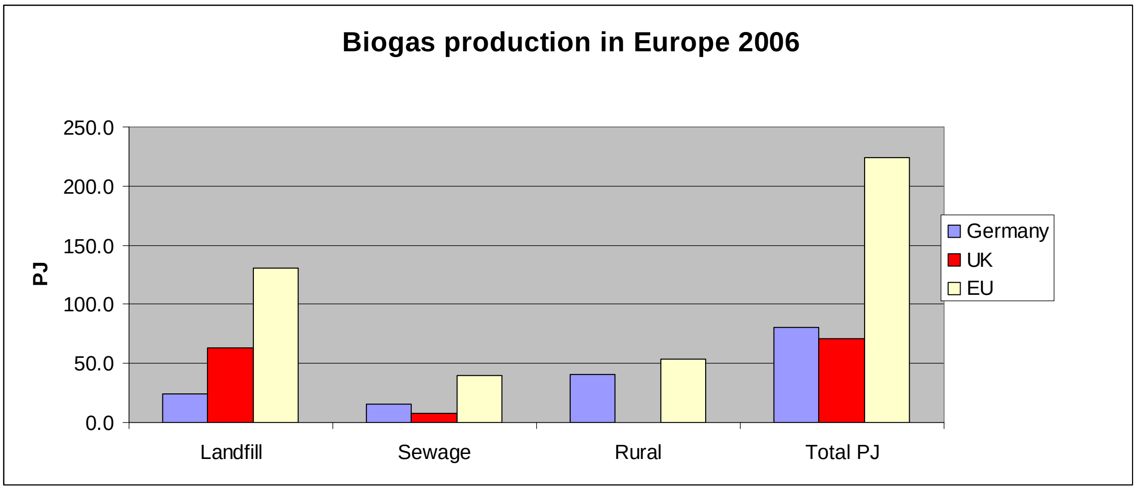
- evaluation of the potential loss of market access from the carbon footprint image of kiwifruit;
- quantification of the potential image value of recycling kiwifruit waste for the generation of biogas;
- comparison of alternative recycling technologies (e.g. Scion’s “Waste to Gold” project, other food products);
- approval of the go-ahead of the project in principle;
- selection of a suitable business model and business partners;
- securing of kiwifruit waste and co-substrates,
- selecting a suitable plant location and business case,
- securing of markets for the energy and fertiliser,
- selection of overseas technology partners,
- testing of the anaerobic digestion of kiwifruit in a test-reactor,
- designing the process,
- sourcing of proven technology,
- procurement of technology and components.

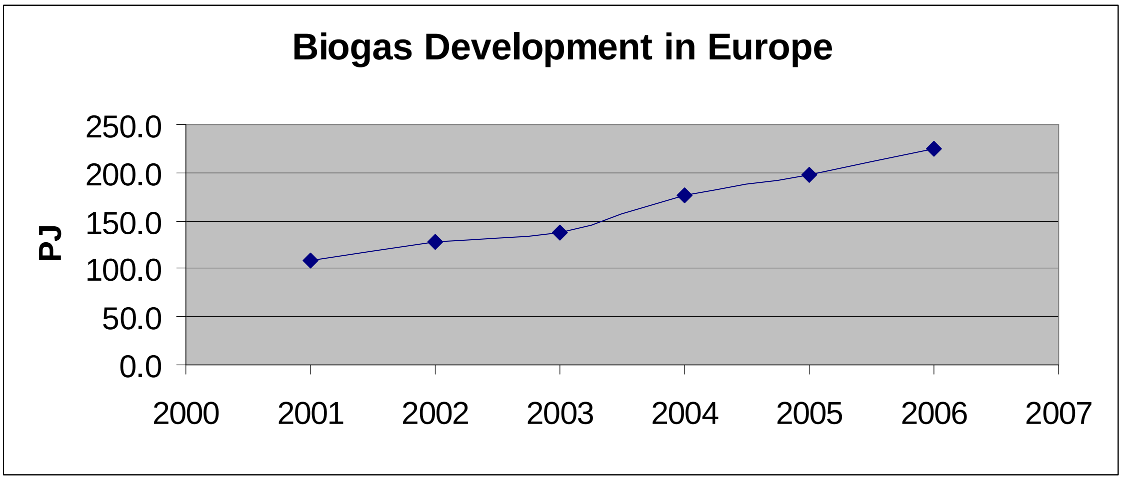
1.0 Introduction

1.1 Background

Biogas has become very popular overseas in a number of Zespri's target markets. For example in Germany, biogas has traditionally been produced in more than 10,000 communal waste treatment plants and, recently, in about 4,000 dedicated biogas production plants. These plants are mainly installed in the farming sector and often used for the conversion of animal manure and crop waste into biogas for combined power and heat.

The following two graphs, produced by the European Biomass Industry Association (Brussels), show this trend. Europe has seen biogas growth rates of 25 PJ per year, which is about 25% of New Zealand's annual natural gas demand.





Source: European Biomass Industry Association

Typical farm scale biogas plants consist of one or more biogas reactors, which use bacteria for anaerobic digestion of organic material. The produced biogas mainly consists of methane (~60%) and carbon dioxide (~40%), and the associated co-generation plants produce grid power and process heat in form of hot water or steam. Electric power outputs range between 300 and 1000 kW.

New Zealand has some experience with biogas, which has been generated in sewer treatment plants and by extraction from landfills and which has often been a coincidental by-product rather than the objective of the process. The technologies used in New Zealand for biogas production from landfills and sewer treatment plants have usually been simple and are characterised by low conversion efficiencies ranging from 10 to 40%. The advanced biogas technologies that have evolved mainly in Europe during the past 10 years have been based on a better understanding of the bacterial process leading to shorter reaction times, smaller vessels and better project economics.

With the decline of the Maui and Kapuni gas fields, New Zealand has woken up to the fact that mineral energy reserves do not last forever. The government started promoting sustainable energy and reduction of carbon emissions, which has improved the political environment for renewable energy. There is now great interest in sustainable energy around the world and also in New Zealand, and many companies with large energy demand start looking into alternatives to fossil fuels.

Biogas has the potential to become an alternative to natural gas on the basis that New Zealand has a small population with a large land area. To substitute the current natural gas demand of 100 PJ with biogas, about 500,000 ha of land would be required for the growing of energy crops such as maize. This is a relatively small fraction of land compared with the 15 million ha of arable land in New Zealand.

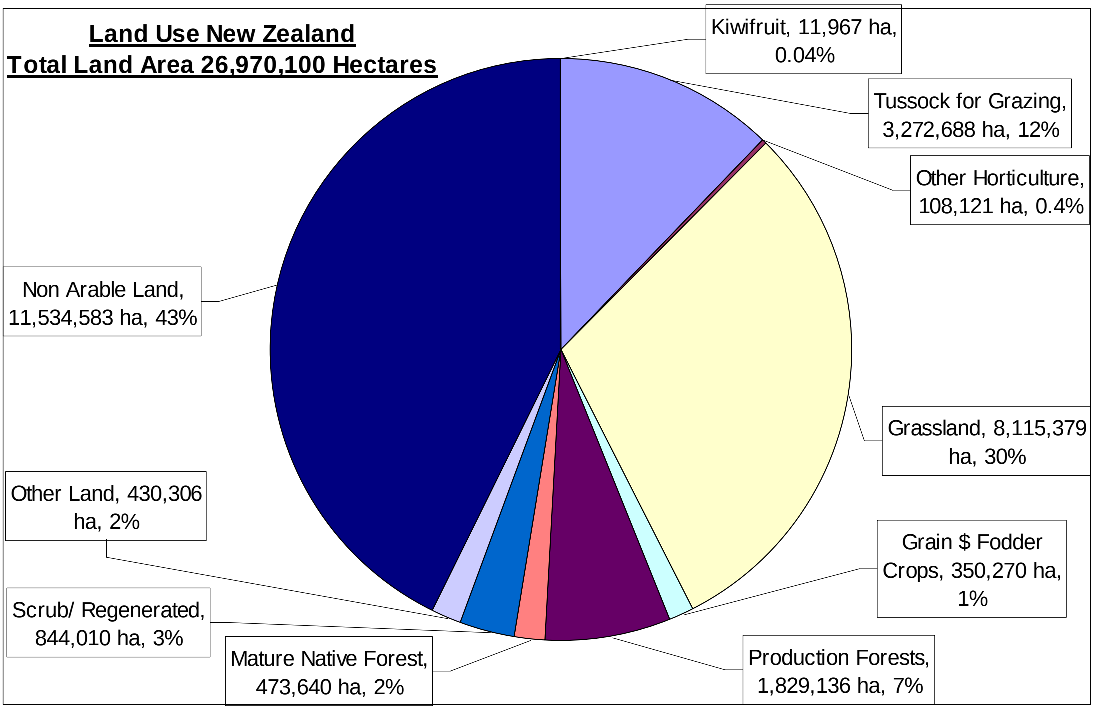
New Zealand farming is developing from an extensive into an intensive farming economy. The kiwifruit industry is a good example. A key current constraint is the shortage of available, low cost labour, which can partly be compensated by technology and energy. The challenge to New Zealand is increased productivity with the same amount of labour and reduced imported fuels. Compared with industrial nations, New Zealand has the scope to increase farming productivity by 30 to 50% and could therefore easily use 20 to 30% of its organic matter for the production of biofuels. Biogas is the simplest biofuels technology and can be made from organic waste, which typically makes 10 to 20% of the production.

With the current economic climate in New Zealand, the growing of energy crops has not picked up yet. Therefore, the focus of biogas conversion should be on organic waste streams, particularly where waste disposal has environmental impact and incurs expenditure. A typical example would be organic waste that is deposited on landfills at the cost of the disposal fee plus the environmental damage caused by leaking landfill gas, which is mainly methane with a greenhouse gas potential of 21 times of that of CO_2.

A further opportunity is the decentralised nature of biogas plants, as the capacities of the national power and gas transmission grids do not need to be increased where the rural energy demand is generated locally.

In New Zealand, Kiwifruit is grown on approximately 10,000 ha of land and produces $1 billion of export value. In comparison, dairy farming occupies approximately 2.0 million ha, producing $ 7 billion export value.

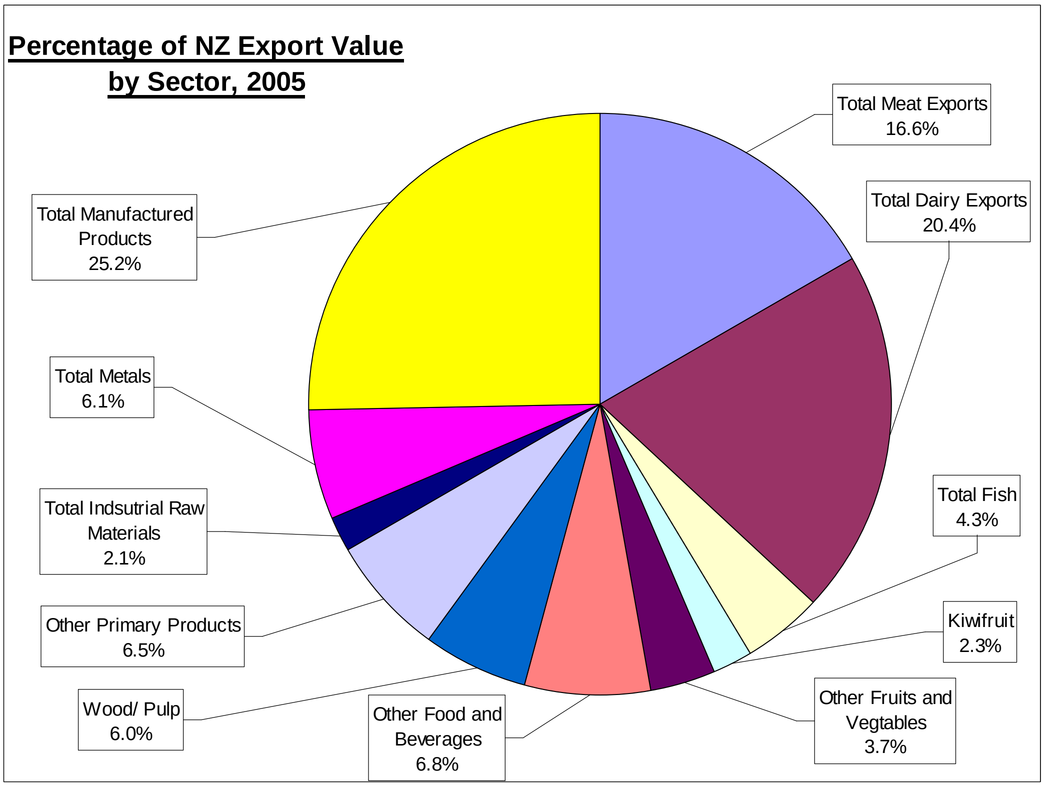
The charts below shows the relative small land area occupied by kiwifruit production and the export values that are produced from these areas.



Source: Ministry for Agriculture and Fisheries

This shows that kiwifruit is a high value producer per ha of land. Compared with dairy or crop farming, however, kiwifruit production is very labour intensive, which is one of the main reasons for the enhanced value achieved on Zespri's target markets. This is a key message in the carbon footprint discussion that needs to be communicated to the markets.

In comparison with other exported products, Kiwifruit makes up about 2.3% of the export value.



Source: Trade and Enterprise, NZ 2005

1.2 Units, Acronyms and Abbreviations

Units:

bara	pressure rating in bar – absolute
barg	pressure rating in bar – gauge, i.e. above atmospheric pressure
TJ	Terra Joule (equals 1000 GJ)
GJ	Giga Joule (equals 1000 MJ)
MJ	Mega Joule (equals 1000 kJ)
kJ	Kilo Joule (equals 1000J)
J	Joule
MW	Power rating in Mega Watts
kW_{elec}	Electrical power rating in kilo Watts
kW_{gas}	Thermal power rating in kilo Watts
kWh	Kilo Watt hours
GWh	Giga Watt hours, equal to 1,000,000 kWh
g	gram
kg	kilogram
t	tonne (equals 1000 kg)
m	metre
mm	millimetre
ha	land area in hectar, equivalent to 10,000 m^2
mg/l	milligrams per litre
MW	power rating in Mega Watt
PJ	Peta Joule (equals 1000 TJ or 1,000,000 GJ)
l	litre
Sm^3 or scm	volume in m^3 at standard conditions (15^{o}C and 101.325 kPa)
m^2	square metre
yr	year
°C	degree Celsius
kJ/kgC	kilo Joule per kilogram per degree Celsius (Heat Capacity)
W/mC	Watts per meter per degree Celsius (Heat Transfer Coefficient)
$/t.50km	Dollars per tonne per 50 kilometre
$/25t.km	Dollars per 25 tonne per kilometre

Acronyms:

CO_2	Carbon Dioxide
CH_4	Chemical symbol for Methane
NH_3	Chemical symbol for ammonia
VFA	Volatile Fatty Acids
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
AD	Anaerobic Digestion
TS	Total Solids
VS	Volatile Solids
DM	Dry Matter
IRR	Internal rate of Return
NPV	Net Present Value
VOL	Volatile Organic Loading
C:N ratio	Carbon to Nitrogen Ratio
$C_6H_{12}O_6$	Chemical symbol for glucose
KTOE	1000 tonnes of oil equivalent
CSTR	Continuous Stirred Tank Reactor
UASB	Upflow Anaerobic Sludge Blanket

1.3 Terms of Reference

This study named “Biogas from Kiwifruit Waste” refers to
Zespri’s Service Agreement of 19 December 2007 and was prepared in accordance with
Schedule 1 – Project Description for Gate 1: Concept Description – Zespri Innovation -2007.

1.4 Disclaimer

We disclaim responsibility for any loss or damages whatsoever suffered by Zespri or any third party as a result of this study and stress the point that this study is the introduction of an innovative concept, which will require further analysis and design work for turning it into reality.

2.0 New Zealand Biofuels Strategy

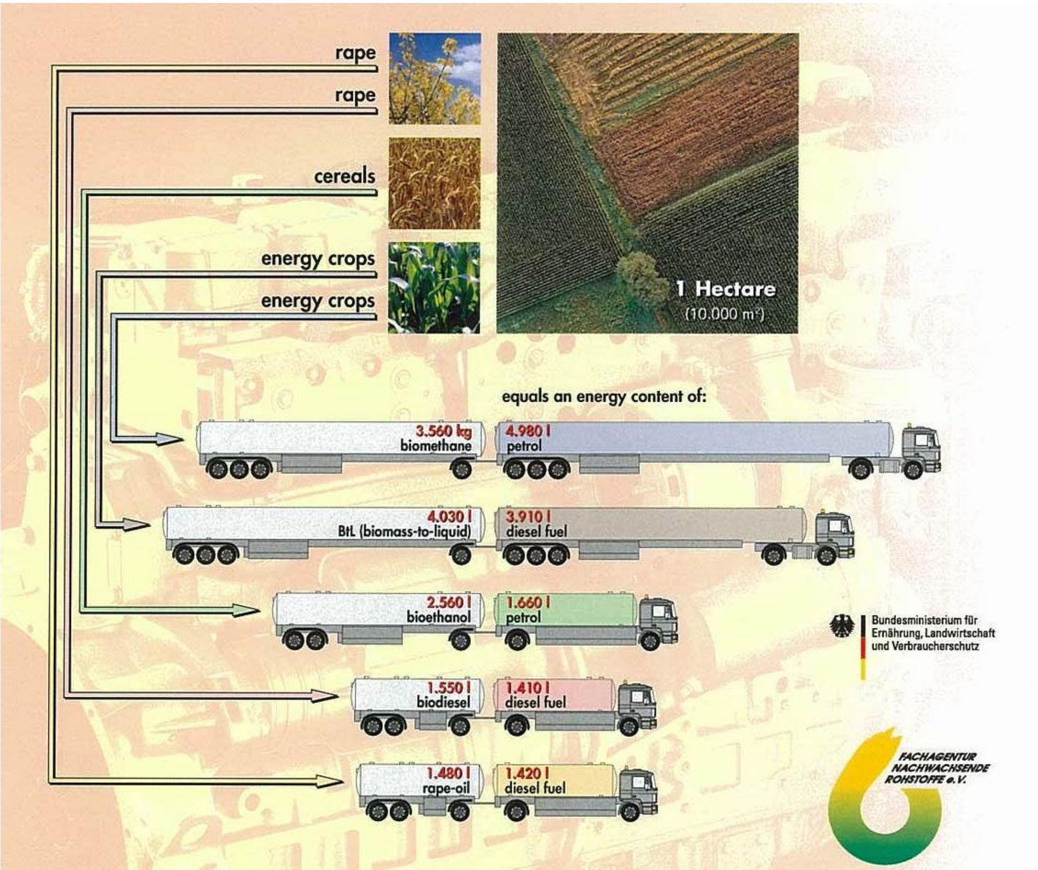
2.1 Introduction

Biogas production from anaerobic digestion of biomass has not been considered in New Zealand in the past as a viable alternative to the current energy mix of oil, gas, hydro, geothermal, coal, wind and wood. The main reasons were the cost of growing biomass and the lack of experience with biogas production in this country.

Biogas has been produced in landfills and sewer treatment plants, typically at small scale, and achieved low levels of energy efficiency at high cost. Biogas was generally a “free” by-product and was only turned into energy if available at minimum cost.

The biofuels discussion has been driven by the New Zealand government’s intention to fuel the economy with a large percentage of renewable energy in the future. In Europe, the popularity of biogas has had three main reasons:

a) anaerobic digestion has the ability to reduce organic wastes very efficiently and to reduce the disposal of waste that would otherwise need to be discharged to landfills at high cost;
b) biogas production has had a reliable track record and can be made from nearly any form of organic waste;
c) biogas achieves the highest yield per ha as compared with liquid biofuels (see picture below), because it can utilise all components of plants.



Source: Ministry for Nutrition, Agriculture and Consumer Protection, Germany, 2006

Biogas has been utilised all around the world for many decades, starting with the extraction of sewer gas. Landfill gas has been extracted and utilised for the past 25 years (in New Zealand for the past 15 years). Animal manure has been digested at places with high concentrations of cattle or pigs, for example, at food lots in the USA and Canada. India and China have had large numbers of small scale pond digesters used for the treatment of animal or human waste.

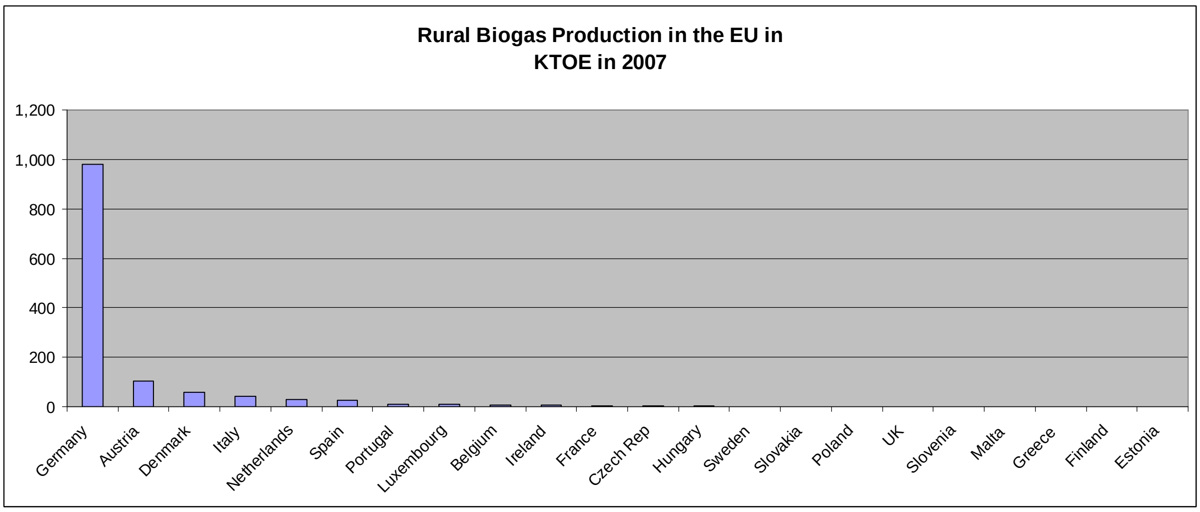
The European countries have recently led the development of advanced digester technologies for the production of biogas from renewable energy crops and from organic waste. The table below shows the total energy production of European countries in tonnes of oil equivalent and GWh in 2006. The table shows the breakdown between landfill gas, sewerage sludge and agricultural wastes.

Primary Energy Production of Biogas in the EU in 2006

Countries	Landfill Gas KTOE	Sewerage Sludge Gas KTOE	Other Biogas (Agricultural Wastes, etc.)	Total KTOE	Total Electricity GWH	TOE/ 1000 INHAB
Germany	573	370	980	1,923	7,338	23
UK	1,515	181	0	1,696	4,997	28
Italy	310	1	42	353	1,234	6
Spain	251	57	25	334	675	8
France	148	75	4	227	501	4
Netherlands	39	51	30	119	286	7
Austria	11	3	103	118	410	14
Denmark	14	23	57	94	285	17
Poland	27	65	1	93	242	3
Belgium	50	25	8	83	237	8
Greece	54	15	0	69	579	6
Finland	51	13	0	63	22	12
Czech Rep	25	31	4	60	175	6
Ireland	25	5	5	35	108	8
Sweden	11	21	1	33	54	4
Hungary	0	7	3	11	22	1
Portugal	0	0	9	9	33	1
Luxembourg	0	0	9	9	33	19
Slovenia	7	1	0	8	32	4
Slovakia	0	4	1	5	4	1
Estonia	1	0	0	1	7	1
Malta	0	0	0	0	0	0
EU	3,116	950	1,281	5,347	17,272	12

KTOE - 1000 tonnes of oil equivalent
TOE/ 1000 INHAB - Total oil equivalent per 1,000 inhabitants
Source - journal of renewable energy May 2007 EurObserver

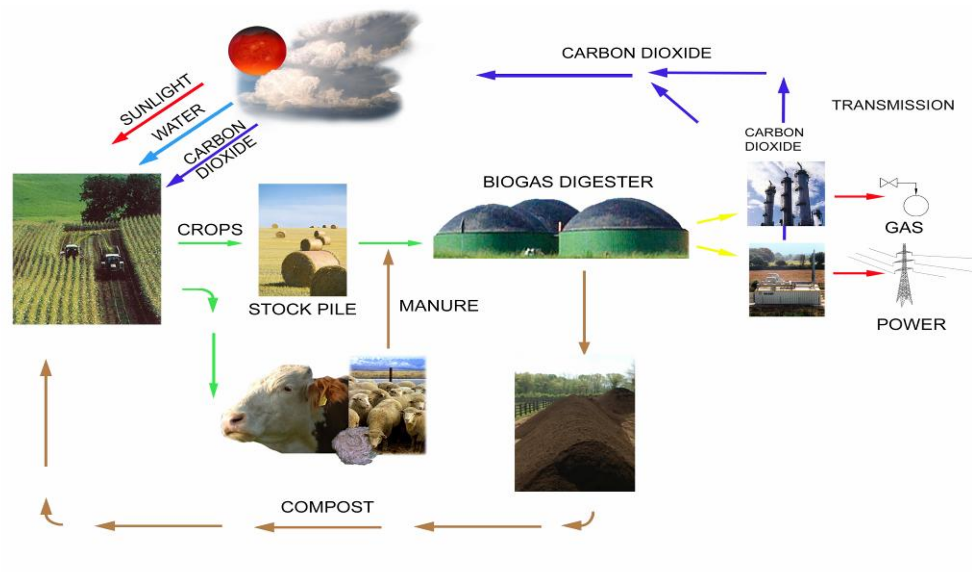
Landfills could be considered dry biogas reactors, however, they are not usually designed as such and the extraction of the gas is usually driven by community demands for a reduction of odour. Biogas reactors are used in sewer treatment plants and in the farming industry. The picture below shows the countries with experience in rural biogas digesters.



2.3 Sustainability

During the past decade, anaerobic digestion technologies have dramatically improved with regard to conversion rate and energy efficiency. This has led to improved, net energy outputs and to reductions of carbon emissions. The biogas production in decentralised plants has the potential for reducing carbon emissions in a number of ways:

- substitution of fossil fuels;
- reducing methane emission from landfills, where waste was discharged
- substitution of industrially-produced chemical fertilizers;
- reduced electrical grid transportation losses



As shown above, biogas conversion is a carbon-neutral, sustainable energy cycle, which includes

- conversion of sunlight, water and carbon dioxide into biomass;
- stockpiling of biomass;
- anaerobic digestion and conversion into biogas for utilisation in boilers or co-generation plants;
- carbon emissions to atmosphere;
- utilisation of the remaining solids as concentrated fertiliser.

2.4 New Zealand Biogas Potential

New Zealand is in the fortunate position of having sufficient land for the production of biofuels for its domestic energy demand. Natural gas reserves could be depleted within 10 years and the only current alternative seems to be the importing of LNG. Biogas could be a viable alternative to LNG, particularly in view of rising energy prices and rising pressure to reduce carbon emissions. In order to substitute the current gas demand of 100 PJ with biogas produced from energy crops, at the current energy yield per ha achieved in Europe, New Zealand would need to use approximately 500,000 of its 15 million ha of arable land for the growing of energy crops such as maize.

Liquid biofuels make up about 250 PJ of New Zealand's energy demand. To grow this amount of energy from crops such as rape seed or canola, about four million ha of land would need to be converted from the current pasture growing. Waste streams from ethanol or bio-diesel production would be sufficient for biogas production of the entire current demand of 100 PJ.

3.0 Kiwifruit Waste Analysis

3.1 Waste Composition

The main waste streams in the kiwi fruit industry are made up of the following:

- **Pruning Waste**, which is usually left on the orchards and turned into mulch and compost; this stream is not further considered available for potential biogas production;
- **Fruit Waste**, which is rejected fruit originating at the pack houses at various stages of packaging and inspection and which is the main focus of this study; Scion recently investigated the amount of fruit waste with a survey and came to the conclusion that between 16 and 18% of the fruit was rejected; 95% of the rejected fruit was given away to farmers as supplement for animal fodder, for which they paid 0 - $10 per tonne;
- **Kiwifruit Hair,** which comes of the plants at various processing stages at a total quantity of 70,000 kg per year or 0.02% of the total production is mainly used by orchards as compost and is not further considered available for biogas;
- **Cardboard boxes, Wood Pallets, Plastic Packing Straps and Shrink Wrap,** which get damaged, are often disposed on landfills; some companies recycle materials where this is possible;
- **Food waste and sewerage** has not been quantified and was therefore not included for the purpose of this study.

3.2 Waste Stream Quantification

In accordance with Zespri's figures the total kiwifruit production in 2007 was 312,000 tonnes, of which more than 50% was produced in Tauranga and TePuke, which could be considered the heart of the kiwifruit industry.

	Kiwifruit production tonnes/ yr	Waste from 16% rejected fruit tonnes/ yr
Total NZ production	312,000	49.920
Production near Te Puke	170,000	27,200

Scion's analysis found that 16 to 18% of the fruit in 2007 was rejected fruit waste.

To be conservative, we considered that 50% of the fruit waste could become available for biogas production if the other half of the pack houses would continue their current practice or do something else with their waste. This would be a mass of 13,600 tonnes per year with most of the waste being produced during six months.

3.3 Energy Content of Waste

Various methods can be used for the calculation of the energy content of the volatile, organic solids contained in kiwifruit. One common way is the consideration of the nutritional energy and another one is the assessment of carbon that can be turned into energy.

The key facts are the moisture content and the key nutritional elements that contribute to the generation of energy, Carbohydrates, Protein and Fat. Further details are in Appendix B or on the web site referred to in this appendix. On that basis, the energy can be calculated as follows:

	Weight (grams)	Moisture content (%)	Dry Weight (grams)	Carbo-hydrates (grams)	Protein (grams)	Fat (grams)	Total Energy kJ
1 kiwifruit	76	83	13	11	1	0.5	219
1 kg	1,000	83	170	150	10	5	2,857
1 tonne	1,000,000	83	170,000	150,000	10,000	5,000	2,857,000

Source: www.nutritiondata.com

The total energy contained in kiwifruit with the above, average moisture content is therefore 2.86 MJ / kg or 2.86 GJ / tonne.

While in theory all of this energy could be digested and turned into biogas, the technological practice suggests that only 70 to 80% is converted, as otherwise the retention times in the digesters become too great, resulting in very large vessels and high costs.

To be conservative, we considered that a conversion rate of 70% would be realistic, which resulted in a practical energy yield of **2.0 GJ/tonne**.

At 37^{o}C, mesophilic bacteria will produce biogas a with approximately 60% Methane (CH_4) and 40% Carbon Dioxde (CO_2) resulting in a calorific value of 22.2 MJ/scm.

At a conversion rate of 70%, biogas production would be 54m^3/ tonne. This is equivalent to 2.0 GJ of energy per tonne of digested kiwifruit waste.

	% Moisture	% Total Solids	% Volatile Solids	CH_4 m^3/tonne	Biogas @ 60:40 m^3/tonne	Energy GJ/tonne	Energy kWh/tonne
1 tonne Kiwifruit	83	17	86-92	54	90	2.0	556

Total Energy Potential from Kiwifruit Waste:

	Waste @ 16% Kiwifruit Tonnes/ yr	Energy GJ/ 6 months	Energy kWh/d over 182 d	6 month avge Power Output kW_{gas}	6 month avge Power Output kW_{elec}
NZ Production	50,000	100,000	153,000	6,400	2,200
Te Puke & Tauranga	27,200	54,400	83,000	3,462	1,200
50% of TePuke/Tauranga	13,600	27,200	41,500	1,731	**600**

3.4 Environmental Impacts of Kiwifruit Waste

This study is only concerned with potential environmental impacts from kiwifruit waste and its potential conversion into biogas, and other impacts from growing and distribution are not further discussed.

The current practice is using the kiwifruit waste as supplementary animal fodder. The fruit waste is assumed to be dispersed over a range of dairy and beef farms, which will have some effect on the manure production per ha of pasture. While manure discharges to land have increased and in some areas have an impact on the ground water, we assume that the incremental manure discharge from kiwifruit feeding is relatively insignificant. The picture below shows a typical dairy farm in New Zealand.

A biogas plant in the Tauranga / TePuke region could possible look similar as the picture below showing a typical farm biogas plant in Germany. The most visible elements would be the digester (s) with a combined volume of about 2400 m^3 and a 500 kW containerised power generator near one of the kiwifruit packing houses.

Apart from the visual impact, that is meant to be beneficial for Zespri's advertising, other potential environmental impacts are:

- Noise
- Emissions to air (CO_2, NO_x, and other combustion products), methane, H_2S
- Odour
- Traffic from trucks transporting kiwifruit to the plant
- Waste water discharged to land or into rivers.

Modern biogas technology can mitigate these environmental impacts. The costs associated with environmental management largely depend on the requirements of the local community. A plant located at one of the pack houses is likely to have a range of environmental features, such as odour control and waste water treatment.

If a potential biogas plant for kiwifruit waste would be located at an industrial site, e.g. at the Affco plant in TePuke, the site would overall gain environmental benefits because of the biogas plant reducing odour emissions and waste water contamination. The digester would be integrated into the existing waste water treatment system.

In both cases, traffic is not a major issue as the plants have existing traffic demands from coming and going trucks.

3.5 Packhouse and Orchard Locations

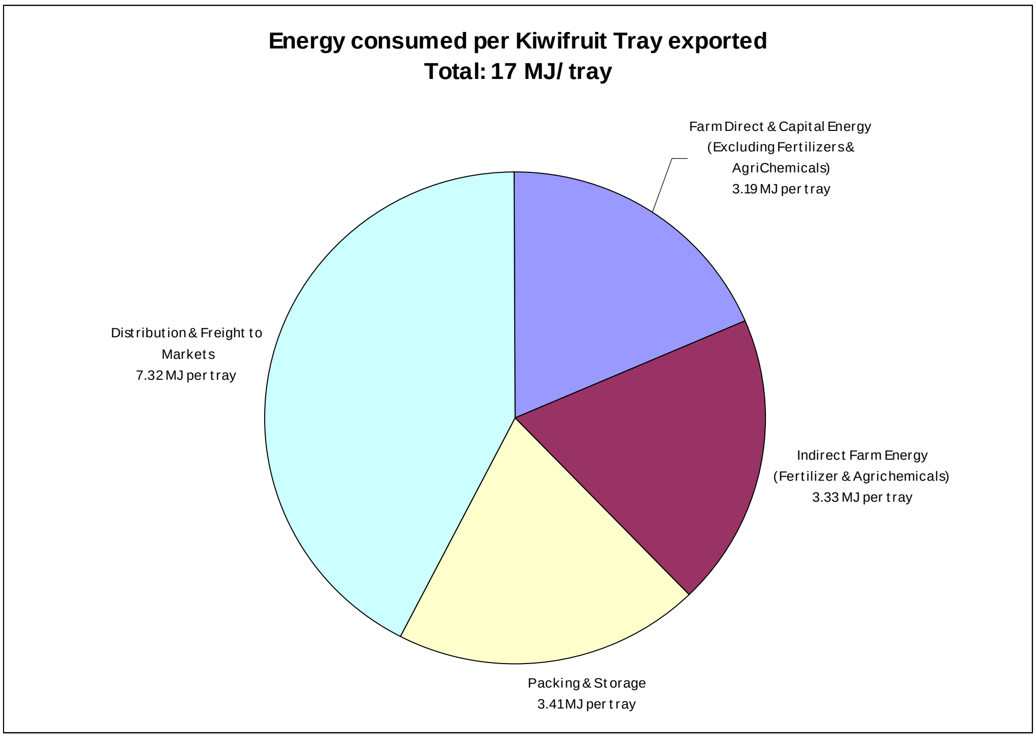
Most of the kiwifruit production is in the Bay of Plenty with a particular concentration in the Tauranga and TePuke region. In accordance with Zespri's analysis in Appendix A, most of the 52 pack houses are located in TePuke and Tauranga processing most of the volume.

This high concentration would minimise transport costs of waste kiwifruit between orchards and pack houses or between pack houses and some central biogas plant located at another industry or a communal site.

4.0 Packhouse Energy Demand

4.1 Industry Energy Consumption

The energy consumption of the New Zealand kiwifruit industry has been analysed by Zespri as part of its efforts in improving energy efficiency and reducing its carbon footprint. We understand that the energy consumption of pack houses was derived from an energy analysis of Aerocool. While individual pack houses will have different, absolute and specific, energy demands, the Aerocool demand was chosen as typical for the industry.



Source: Aerocool Report, Food Miles Report & Zespri Energy Audit

The main streams of energy consumed in the production, packaging and distribution of kiwifruit are shown in the chart above. They consist of the following components

- direct farm energy consumption is 3.19 MJ/ tray, which is made up of diesel and other forms of energy consumed by machinery and buildings;
- indirect farm energy of 3.33 MJ/ tray is consumed in the manufacturing and transport of fertilisers and agri-chemicals;
- packing and storage energy of pack houses is 3.41 MJ/ tray.
- shipping and distribution energy used to carry the fruit to markets is 7.32 MJ/ tray.

4.2 Packhouse Operations

The kiwifruit harvesting season starts in mid April with a 2 month intensive picking season where fruit is arriving on site. Often, two shifts work during this period in selecting and packaging the fruit, which is either prepared for export or sent into cool storage with controlled atmospheres for later shipment.

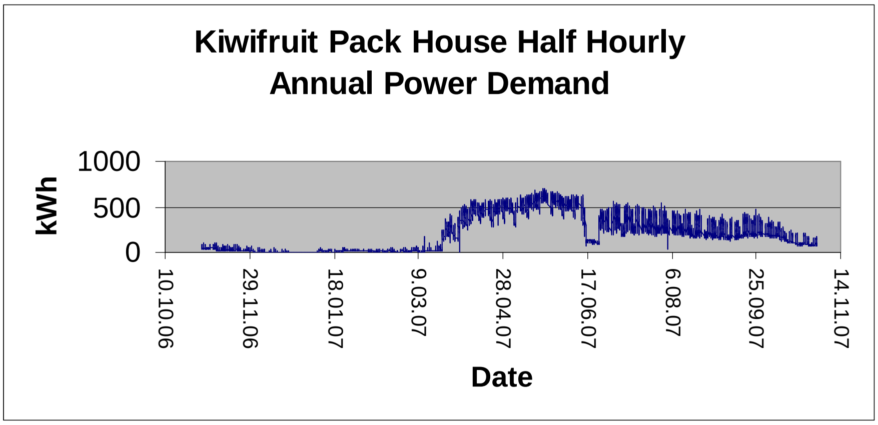
After the harvest period until September, fruit is withdrawn from storage, re-inspected and packaged for export. As the quantities and the hours of packing reduce, the energy demand for cool storage and machinery gradually reduces too.

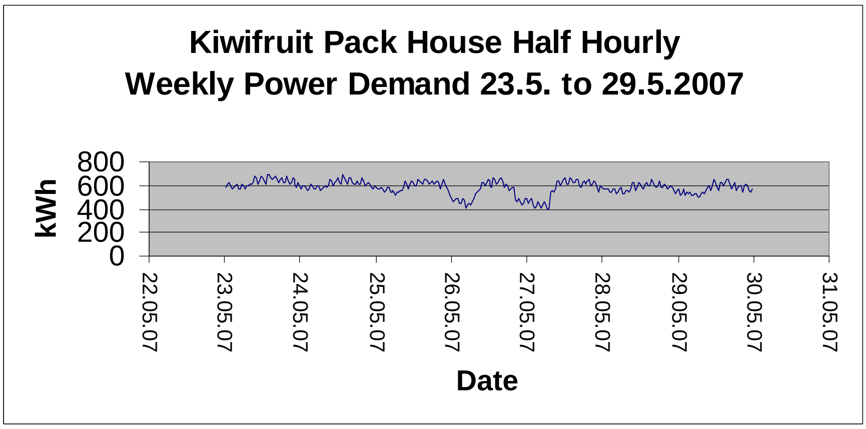
The energy consumption falls off at the end of October, when remaining quantities from the cool stores are cleared out for exports. This is the time when kiwifruit produced in the northern hemisphere is coming to the markets and when the quality of the New Zealand fruit starts dropping. The last batches often have high percentages of waste.

The energy demand during packing and storage was analysed in an energy audit of the Aerocool pack house at Mt Maunganui. This pack house processed approx. 1.05 million trays and used 1,000,000 kWh of power during one year. This is equivalent to 3.41 MJ/ tray. Approximately 80% of the energy was used for refrigeration of fruit. The other 20% were used for machinery, lighting, heating, office tools and kitchen equipment.

4.3 Pack House Load Profile

One of the largest pack houses at TePuke provided us with its half-hourly energy demand, which showed the following load profiles:





The charts show the annual and weekly load profile. The demand in kW can be calculated from the half-hourly energy consumption (kWh) multiplied by two. In this case, the base load during the later months of the season is close to 500 kW, which would approximately be the rating of a potential generator at this site.

4.4 Energy Prices

Biogas can supplement both forms of reticulated energy, natural gas and power. Most of the energy consumed at pack houses is electricity used for refrigeration with compressors driven by electric motors. While there are gas fired refrigeration plants on the market, the conventional form of cooling is through mechanical power. Machinery and lights generally use electricity.

The natural gas transmission network has a feeder line going to Tauranga and TePuke (up to Rangiuru) and a number of large industries have gas fired boilers for process heat, both in Tauranga and TePuke. This opens up opportunities for installing biogas plants at or near industrial sites that use gas. The advantage would be the reduced capital investment for a gas fired boiler as compared with a power generator (see Appendix C). Where biogas plants feed a power generator, the waste heat coming from that generator could supplement natural gas.

The benchmark prices for these forms of energy are:

- Power: 10.0 cents / kWh
- Gas: $10.00 per GJ

These prices are the variable components of industrial energy prices in 2008. While embedded generators may be able to negotiate a reduction of their fixed prices in the future, currently only the variable component can be saved when the demand of an industrial plant is reduced. Prices vary depending on load, location, season and energy retailer. Fixed costs consist of transmission, distribution and metering charges and reflect the capital spent on the network components relevant to the plant. These are typically in the order of 50% of the variable costs, depending on location and load pattern.

Some contracts are linked to the power pricing of the New Zealand spot market, which can vary between 5 and 50 cents / kWh, depending on the availability of hydro power.

The above, variable energy prices were used for our economic analysis.

4.5 Energy Demand at Other Industries

Because of the seasonal load pattern of kiwifruit pack houses and the slightly acidic nature of kiwifruit, it is likely that kiwifruit waste would be mixed with a co-substrate, such as maize, food waste or manure. In this case, the co-substrate would either be transported to the kiwifruit biogas digester, or the kiwifruit would be transported to the digester of the co-substrate. In TePuke, this could be the Affco meat processing plant, or in Tauranga, the digester of the sewage treatment plant.

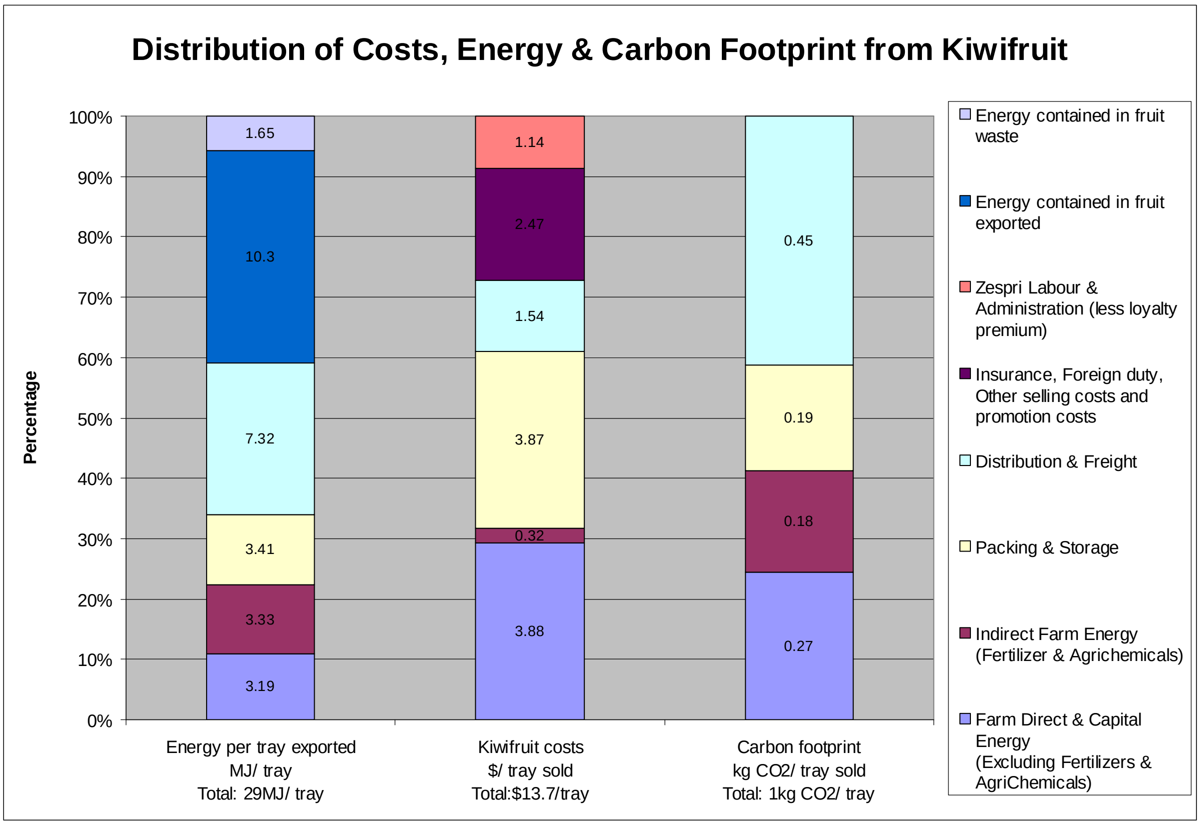
The mix of substrates will determine the size of the plant and the use of energy. In most cases, the energy demand of these other industries will be greater than the energy produced by the biogas reactor. This has the advantage of better tariffs downstream of the meter and not needing to export surplus energy to the grid at lower rates. While the government has recently introduced legislation to help embedded generators getting better tariffs, it will take some time until distribution companies and retailers will reduce their network and metering fees.

Typical biogas plant sizes range from 1,400 kW_{gas} / 500 kW_{power} to 2,400 kW_{gas} / 1000 kW_{power} . The thermal efficiency of gas engine driven generators for these plant sizes is about 35% to 40%, which is reflected in the above output ratios. Plant sizes below 500 kW_{power} become relatively expensive per installed rating and plant sizes above 1000 kW_{power} often incur larger transportation costs for the collection of the substrate.

Where the biogas is used in boilers for process heat, it could be viable to have gas outputs below 1,400 kW because of the low cost of boilers. This could be attractive for smaller demonstration units.

4.6 Energy, Cost and Carbon Footprint of Kiwifruit production and sale

In order to relate the energy recycling of the fruit waste with the carbon footprint debate, we have prepared the chart below.



Source of data: Zespri - Aerocool Report, Food Miles Report, Energy Audit & Annual Report 2006/07

This chart shows that the energy gained from utilising the fruit waste is small compared with the energy that relates to the carbon footprint. The fruit waste is only a small fraction of the total fruit production and the energy that can be "recovered" is only about 10% of the energy required. Biogas production can therefore only be one of a range of efforts that the industry will need to make to improve its sustainability.

The consumer may have a very different perception of the carbon footprint of kiwifruit, most likely based on emotions rather than on quantitative analysis, which would be good to research and understand.

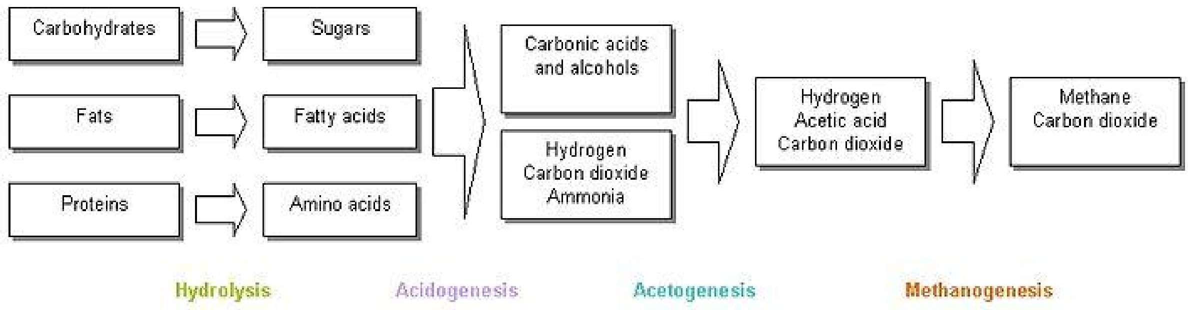
5.0 Biogas Process

5.1 Anaerobic Digestion

Anaerobic digestion is a process, in which micro organisms break down biodegradable material in the absence of oxygen. The process has been widely used in the treatment of wastewater sludge because of its effectiveness and low energy consumption (e.g. compared with aerobic waste water treatment). In addition, it provides net energy that can be utilised for other components of the waste treatment. The remaining solids downstream of an anaerobic digester require less energy for environmental treatment and can be converted into valuable mineral fertilisers.

The breakdown of nutrients and digestion process consists of several stages and involves different bacteria as shown below:

The key process stages of anaerobic digestion



The know-how in plant design and operation is largely based on the understanding of the environmental conditions required by each strand of bacteria. This requires experience and careful process control that is generally missing in New Zealand. A large part of the technology transfer will be the training of New Zealand plant operators.

Particular care is required for the mixing of substrates, loading and discharge rates, solid / liquid concentration, temperature, pH Value and gas demand management. Also the ancillary processes like sludge treatment, water treatment, air treatment and gas treatment are important and add to the complexity of a modern biogas plant.

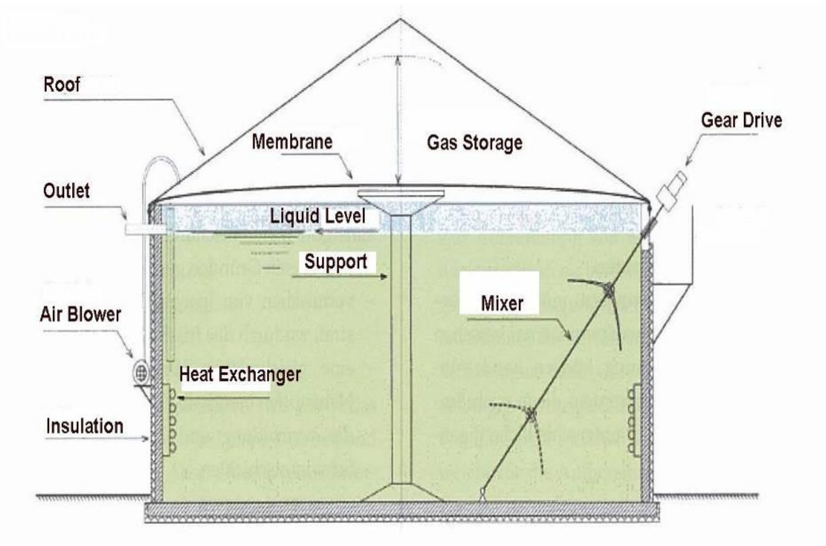
In Europe, many biogas digesters are now operated by farmers, who have developed a good understanding of the process and technology. National biogas industries, like that of Germany, have available a wide range of services and equipment to choose from. One reason why New Zealand has not yet adopted this technology is its relative remoteness to the industrial centres of the world. The introduction of biogas technologies in New Zealand will take time, money and persistence.

Of all biofuels processes, biogas has the best track record in New Zealand and is the least complicated, the most versatile (with regard to substrates) and the most economic process.

5.2 Digester Designs

The heart of a biogas plant is the digester. The most common type is the wet digester, which principally consists of an insulated vessel, made from concrete or steel, with a number of elements including:

- intake and discharge piping and baffles;
- heating coils for temperature control;
- mixers or stirrers;
- gas storage membrane
- gas storage control
- roof.



A typical, modern digester plant looks similar as the picture below:

Source: Schmack AG

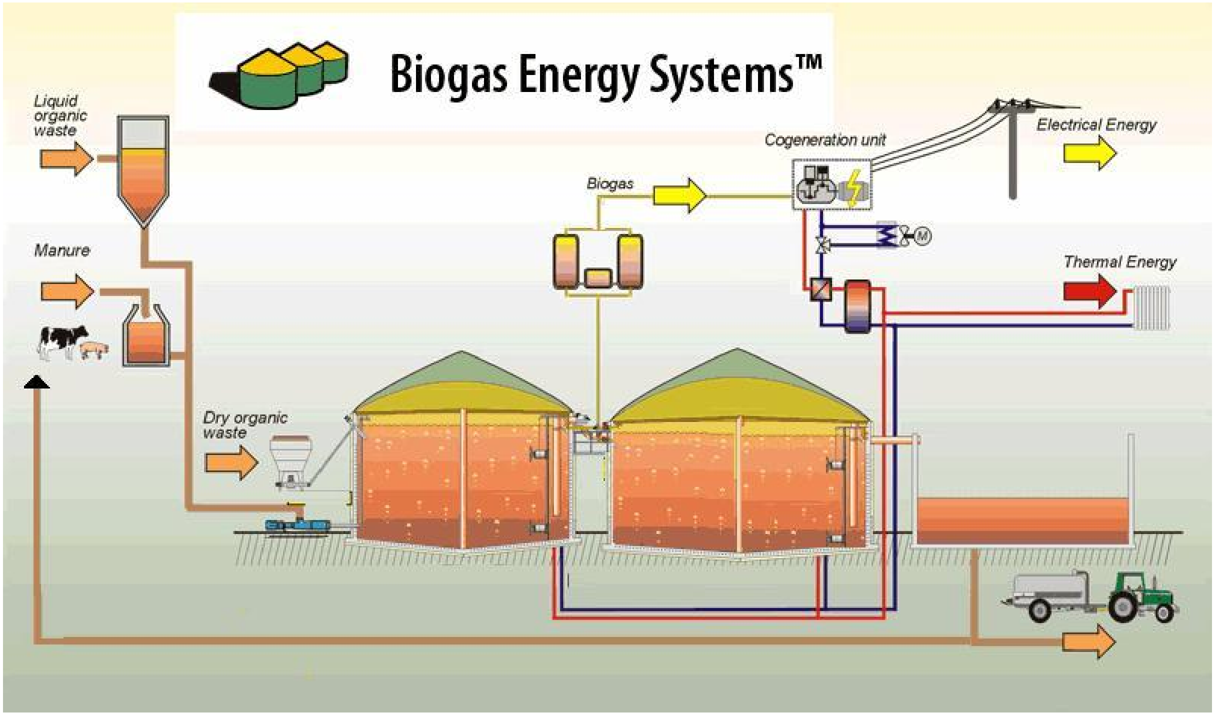
This one consists of a number of components such as:

- a containerised co-generation plant
- a make-up tank
- a flare
- and a material handling shed.

Further plant complexity may be required depending on the substrates, the industry and environmental conditions. Ancillary equipment may include:

- substrate storage;
- substrate make-up;
- chemical control;
- waste water treatment and storage;
- sludge treatment and storage
- gas treatment and storage;
- gas utilisation;
- waste heat recovery;
- air treatment.

A simplified process diagram is shown below, which shows a two-stage digestion of mixed substrates, in this case cattle manure, liquid organic waste and dry organic waste:



Source: www.biogas-energy.com

Anaerobic digesters can be designed and engineered to operate in a number of different process configurations, for example:

- batch or continuous
- mesophilic or thermophilic bacteria
- high solids or low solids
- single stage or multistage

One of the key controls for optimised bacterial activity is the **temperature control**.

Two temperature levels are common for anaerobic digesters, which are determined by the species of methanogenic bacteria in the digesters:

- *Mesophilic* bacteria are most active around 37°-41°C and can survive at ambient temperatures; this is the more common process;
- *Thermophilic* bacteria are most active around 55°C; these bacteria have a higher conversion rate compared with that of mesophilic bacteria, however, they are more sensitive to temperature fluctuation caused by unsteady temperature control, which is why this process is not so common.

The picture below shows the controls of a biogas reactor.

Source: Biogas Nord AG

The **residence time** in a digester varies with the amount and type of feed material, the configuration of the digestion system and whether a one-stage or two-stage process is chosen. Also, the process temperature and the type of bacteria have influence on the optimum residence time. Residence times generally vary between 10 and 40 days and affect the conversion efficiency and the capital cost of the plant.

Biogas is produced at the final stage of bacterial activity, the Methanogenesis. The gas contains mainly methane and CO_2 as well as some trace elements, such as hydrogen sulphide, as shown in the adjacent table.

Biogas would be classified as a lean gas. It has a calorific value of 20 to 22 MJ/scm, which is about half of that of natural gas in New Zealand. Compared with natural gas, biogas does not burn as well and appliances that run on biogas need certain modifications.

The gas would typically be used in steam or hot water boilers or in reciprocating gas engines for the generation of power and process heat.

Typical composition of biogas

Matter	%
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50
Nitrogen, N_2	0-10
Hydrogen, H_2	0-1
Hydrogen sulphide, H_2S	0-3
Oxygen, O_2	0-2

Digestate is the solid remnants of the original input material to the digester that the microbes cannot utilise. It also consists of mineralised remains of the dead bacteria from within the digester.

The digestate is rich in nutrients and can be used as a fertiliser depending on the quality of the material being digested. The digestate is usually drawn off the bottom of the digester in form of a concentrated sludge. The mass of the solids contained in the digestate is about 20 to 25 % of that of the original substrate. The balance is found in the biogas and water.

The digestate is often simply used in liquid form and sprayed over fields. Alternatively, it can be dried, composted, deposited on landfills or used as organic, mineral rich fertiliser. If used as compost, the digestate needs to be mixed with air to start a phase of aerobic decomposition in order to improve the quality of the compost. Depending on environmental conditions, the air will need to be treated to avoid odour.

The third output from anaerobic digestion is **water**. This water originates both from the moisture content of the original substrate and from water produced during the microbial reaction. Water may be separated from the dewatering of the digestate or may be directly drawn from the digester. It will typically contain high BOD and COD that will require further treatment prior to being released onto land or into water courses or sewers. This can be achieved through oxidisation in open ponds or closed vessels.

5.3 Gas Supply and Demand Management

The anaerobic digestion is ideally been done in a continuous process, which means that feeds and discharges will need to be buffered to match supply and demand. It is therefore important to find a load that is relatively steady. In an ideal case, the energy demand of the associated industrial plant would be large and steady, so that the produced energy from the biogas process could be absorbed at the rate of production. Where the energy demand fluctuates, e.g. between day and night or between week days and the weekend, a gas storage will need to be installed. This storage will in most cases be operated at pressures near atmospheric pressure, and the variable volume will be provided by a gas holder.

Traditional gas holders, as used in the early days of coal gas reticulation, were large bells sealed by water. Modern biogas plants have been using flexible membranes made from reinforced plastics, which were either fitted on top of the digesters or as separate containers as shown on the photo below.

These gas holders usually consist of two membranes, with the outer one acting as a roof and the inner one as the actual gas bladder. The gap between these two membranes is filled with air, which is held at the same pressure as the gas inside the holder by using a blower.

Source: Haase GmbH

6.0 Plant Configuration

6.1 Plant Concept

The plant concept and layout depend very much on the type of substrates, the environmental conditions as well as the utilisation of the energy.

For a first visualisation, we considered a plant with a gas production rate big enough to run a co-generation plant with 500 kW power output. The substrate would be a mix of kiwifruit waste, cattle manure and meat processing waste (paunch and DAF sludge). It would also be able to take other plant or food waste.

The digestion would take place in two stages with digester volumes of approximately 2 x 1200 m^3.

The location would be near an industrial plant with all year power and heat demand with more than 500 kW base load (both power and heat). We considered that this would be exceeded by plants of the magnitude of Affco in Rangiuru near Te Puke. Half of the substrate would be kiwifruit waste, half would be meat processing waste during the time of kiwifruit processing. During the other half of the year, e.g. from November to April, the meat processing waste would be supplemented with other organic waste, such as crop waste or communal green waste, or the reduced gas output could be supplemented with natural gas, or the generator would run on reduced load.

The heat of the co-generation plant would be used for the production of hot water at the plant, and all of the power would either be used by the plant or fed into the grid.

The digestate would be dehydrated and converted into compost fertiliser. The waste water would be treated in the existing treatment facilities of the plant.

The picture below shows a 640 kW plant in Germany.

Source: Biogas Nord AG, 640 kW electrical output

Sample process flow diagrams are shown in Appendix D.

6.2 Ancillary Equipment

In addition to the digester and the generation plant, and depending on the desired complexity of the plant, other ancillary components need to be included, which are listed below:

- Screw Conveyor
- Shredder
- Make-up Tank
- Holding Tanks
- Pumps
- Blowers
- Heat Exchanger
- Coolers
- Separators
- Centrifuges
- Air Stripper Column
- Solids Aerator
- Flare
- Effluent Tank
- Gas Holder

These components will be specified at a later stage of the project.

The type of ancillary equipment and the required performance will depend on operational and environmental conditions and will be subject to detailed design.

7.0 Economics

7.1 Business Model

We analysed two alternatives:

a) a biogas plant feeding its gas to a boiler to produce hot water and
b) a biogas plant feeding its gas to a co-generation plant.

Apart from this difference, both alternatives are identical and the economic performance is also very similar. However, the boiler alternative is simpler and slightly more economic.

In our economic model we assumed the co-digestion of kiwifruit waste with other organic matter, in this case with meat processing waste, which was assumed to be available throughout the year, and with a third substrate, e.g. communal green waste. This would have a number of technical and commercial advantages.

The digester was designed to fuel either a 1.3 MW boiler or a co-generation plant providing 500 kW power and 400 kW continuous heat in form of hot water.

We assumed that the kiwifruit waste provided 50% of the energy of the substrate during six months of the year, which was equivalent to 25% over a full year. The other, main substrate was assumed to be available throughout the year providing 50% of the energy. As mentioned earlier, we considered the Affco meat processing plant at Rangiuru to be a good match. Alternatively, there may be other processing plants in the Bay of Plenty with similarly good conditions. The third substrate could be crop waste, dry manure or communal green waste.

While the kiwifruit waste would only make up 25% of the feed stream in this example, the kiwifruit industry could have a greater stake in the plant. The model is independent of the ownership issue as the criteria are a certain rate of return at which the project should meet a neutral Net Present Value (NPV). The weighted average cost of capital was assumed to be 10.7% on the basis of 50% equity at a cost of 15% per year.

In the model, the kiwifruit waste was purchased at a price of $10 per tonne, which is significantly more than what farmers pay for the fruit waste at the moment. The value for supplemented natural gas was $10 per GJ, as explained earlier, and the variable power price, downstream of the meter, was 10 cents / kWh.

We believe that the compost price of $40 per tonne was conservative as well as the assumed fee of $10 per tonne for the digestion of meat processing sludge. The cost of disposing organic waste in landfills is significantly higher.

We have included carbon credits with a value of $1 per GJ, which is equivalent to a value of about $30 per tonne of CO_2. The New Zealand government is still progressing on developing a carbon trading scheme. While we hope that this will eventually become a commercial reality, particularly for renewable energy, we are rather cautious with this potential value. The reason for including this figure in the project economics was our wish to show the relatively small impact that carbon credits would have on such a project.

We also assumed a purchase price of $5 per tonne for green waste supplementing the meat waste outside the kiwifruit season. It is quite possible that communal green waste is available at no cost.

7.2 Capital Expenditure

The capital costs for the digester components were derived from overseas experience and converted to New Zealand conditions, considering the local cost of labour, energy and the NZ/Euro exchange rate of 1.9.

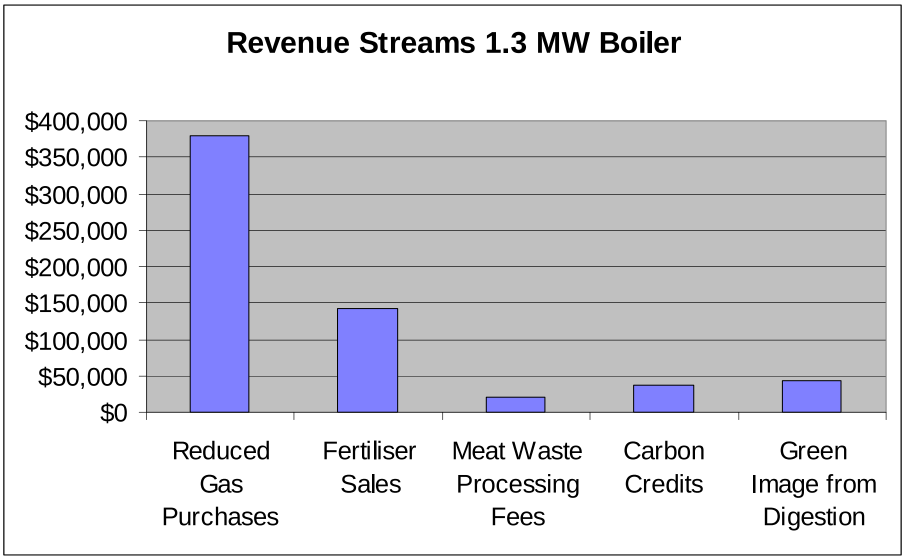
We included licence fees for the involvement of overseas companies. Piping and instrumentation was included in the figures of the main components.

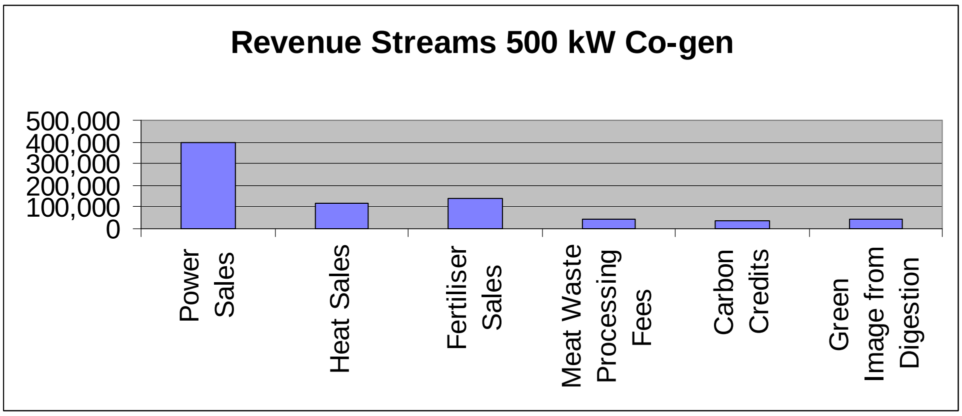
Inclusive of design and project management fees, the two alternatives had the following costs:

a) biogas plant with 1.3 MW boiler: $2.5 million;
b) biogas plant with 500 kW co-gen plant: $3.4 million.

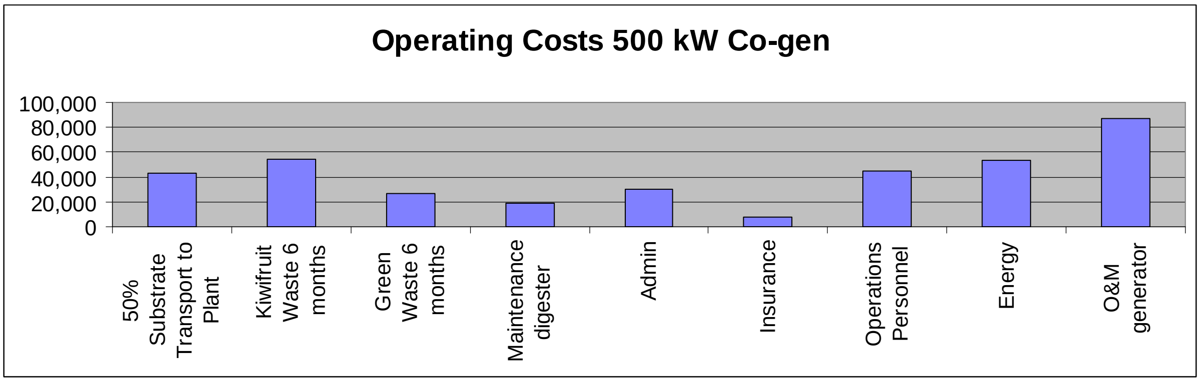
7.3 Revenue

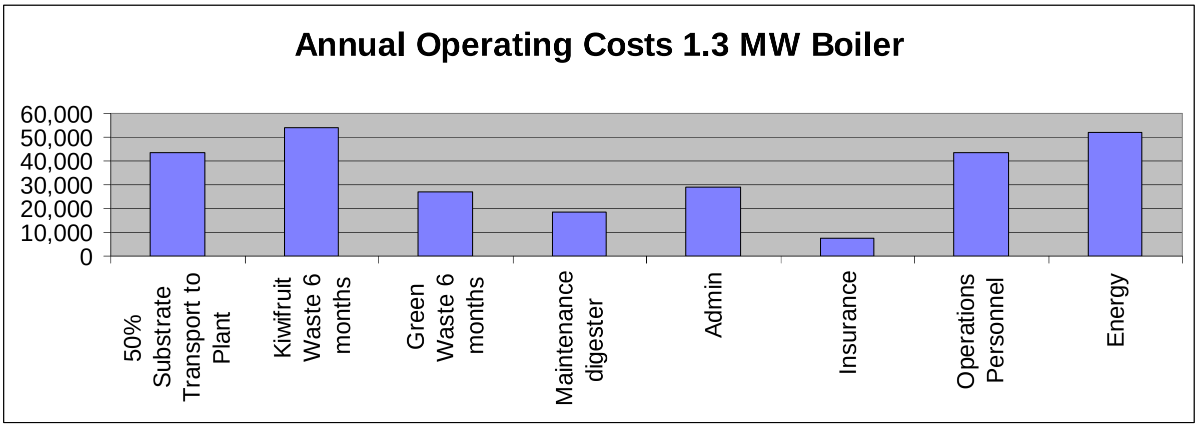
The revenue streams in our models are as follows:





7.4 Operating Costs





7.5 Transport Costs

Transport costs will depend on a number of variables, the frequency of transport, location of transport, length of journey and whether the trailer is pre-loaded for pick-up.

Quoted transport costs are between $4 per tonne and 50km and $10 per tonne and 50km or between $2 per tonne and 25 km and $5 per tonne and 25 km. In our model, we used an average range of 25 km, which would allow for some transport distances up to 50 Km. This would cover all of the Bay of Plenty, if there were two to four digesters at production centres.

7.6 Image Value

One of the drivers of Zespri's efforts in reducing the carbon footprint of the industry is the potential perception of overseas markets of New Zealand kiwifruit having a high carbon footprint. As we showed in section 4.6, the energy that can be recovered from the fruit waste is about **10%** of the energy used for growing, packaging and distribution. While this is small, it is not insignificant, and would be a step in the right direction.

With regard to communicating the message effectively, it needs to be pointed out that kiwifruit is a labour intensive food item compared with basic food like bread and milk. We prepared the two tables below to show the energy related facts for this argument.

2005 NZ Statistics	Kiwifruit	Milk (whole milk)
Land area orchards, farms	9,200 ha	1,410,000 ha
% of NZ arable land (15 mill ha)	0.06%	9.4%
Annual yield per ha	34,200 kg	9,574 l or 9,861 kg
Nutritional energy	2.4 MJ/kg	2.9 MJ/kg
Annual energy yield per ha	82,080 MJ	28,597 MJ
NZ retail price (2008)	$4.00 per kg	$2.2 per kg
NZ price per energy content	$1.46 per MJ	$0.76 per MJ
Overseas retail price, estimated	$10.00 per kg	$2.5 per kg
Overseas retail price per energy	$4.17 per MJ	$0.87 per MJ

While retail prices are estimated and do not reflect annual averages, the above table shows that in New Zealand, consumers are prepared to pay about twice as much for the energy value of kiwifruit than for milk, and this is estimated to be much higher overseas.

Other competing food products, for example, are apples, sugar or bread.

	Apples	Sugar	Bread
Nutritional energy	2.0 MJ/kg	16.5 MJ/kg	10.5 MJ/kg
NZ retail price (2008)	$3.00 per kg	$2.00 per kg	$3.00 per kg
NZ price per energy content	$1.50 per MJ	$0.12 per MJ	$0.29 per MJ

Zespri can clearly point out that kiwifruit is a luxury food with values other than energy content, e.g. vitamins, flavour and quality. In New Zealand, apples and kiwifruit would have a similar price per energy content. Both fruit types are clearly beaten by sugar, which provides pure energy at low cost and bread, which provides energy plus a wider range of nutrients.

The high retail price of kiwifruit reflects the production, packaging, marketing and distribution costs, which are based on labour associated with direct and indirect energy inputs. In the discussion about carbon footprint, it needs to be pointed out that the carbon footprint is related to the amount of processing that goes into kiwifruit. Kiwifruit is a “refined” food item, which is different to bread, milk and sugar.

How much the energy recovery of the fruit waste could be used in the carbon footprint debate, will need to be evaluated. Biogas digesters are highly visible and promote local efforts in renewable energy. In our model, we allocated 0.02% of the export value to the positive image value that may be achieved from biogas production. This was **$0.64 per tonne** and appeared to be a very low cost compared with the export price. How far the image value could be enhanced beyond this figure will largely depend on the effectiveness of communicating the message to the consumers and could become a significant driver for the project.

7.7 Internal Rate of Return

On the basis of a 15-year project life, the internal rates of return (IRR) after tax are:

- **a)** 1.3 MW Boiler option: **12.1%**
- **b)** 500 kW Co-generation Unit: **9.6%**

This shows that the utilisation of biogas in a simple boiler would result in better project economics if all other variables would be the same. However, there are few industries with large demands for hot water or hot air, and the conversion into electricity would generally provide more opportunities for potential biogas plant locations, including kiwifruit pack houses.

7.8 Funding

Our economic analysis showed that the project is marginally economic with the assumptions made in the model. There are many opportunities for improving the economics, particularly by setting up business relationships with good synergy. A key opportunity is using co-substrates that have environmental problems and incur disposal costs. Landfill fees are now in the order of $100 to $150 per tonne of industrial waste, which sets benchmarks for waste disposal.

Digesters are highly efficient organic waste disposers generating energy rather than consuming energy, which are the key arguments in approaching potential business partners.

While the government has a role in supporting renewable energy technologies, we believe that it is up to the industry to make it happen.

There are a number of government funds that can be applied for, and the chances of getting grants are particularly high if new technologies and skill transfer are involved. Some of these funds are:

a) Trade and Enterprise: Regional Strategy Fund
b) EECA: Grants for Energy Intensive Business (EIB)
c) Government / farming industry: NZ Fast Forward

7.9 Risks

There is no business without risk. In the above discussion on project economics, we have pointed out some commercial risks and opportunities. While a detailed risk analysis is outside the scope of this report, we like to summarise some of the risks and opportunities below, without claiming that this is comprehensive or ranked by priorities:

a) Risks:

- finding suitable business partners with organic waste;
- technology transfer to New Zealand;
- capital cost escalation;
- lack of technical skills in New Zealand;
- insufficient funding;
- insufficient interest by kiwifruit industry.

b) Opportunities:

- environmental cost of organic waste;
- image value of engaging in renewable energy;
- image value from being an innovation leader;
- increasing energy prices;
- increasing cost of carbon emissions;
- economic benefits;
- government support;
- community support;
- reduced costs for artificial fertilisers.

8.0 Conclusion

8.1 General

- Anaerobic digestion of kiwifruit waste would be a highly visible effort by the industry for reducing its net energy consumption and improving its long-term sustainability.
- Advanced technology from Europe, which has been proven over the past decade, could be transferred to New Zealand.
- The green image value of energy recycling may exceed the relatively low cost of Zespri's financial contribution to this project.
- Kiwifruit would need to be processed together with other waste streams to improve the process and project economics.
- Anaerobic digestion of kiwifruit waste in combination with other organic waste streams will spread the number of plants, reduce financial risks and transport costs and will increase the visibility of Zespri's innovative efforts with regard to sustainability.
- Our economic model was set up as a conservative base case and returns could be improved by higher value generation from increased income streams and reduced costs.

8.2 Other Energy Conservation Measures

As we pointed out, the use of kiwifruit waste for the generation of carbon neutral energy would only recuperate a small part of the energy being used in the production and distribution. In parallel, the industry should reduce energy consumption wherever possible to show its commitment to sustainability. Typical examples for energy conservation measures are:

- improved insulation and control of cool stores;
- reduced frequency of handling and re-packaging of fruit;
- improved scheduling of transport;
- reduced artificial fertilisers;
- improved efficiency of pest control.

8.3 Project Plan

Further to this study, we recommend the following sequence of action:

- quantification of the potential loss of market access from the carbon footprint image of kiwifruit;
- quantification of the image value of recycling kiwifruit waste for the generation of biogas;
- comparison of alternative recycling technologies (e.g. Scion's "Waste to Gold" project, other food products);
- approval of the go-ahead of the project in principle;
- selection of a suitable business model and business partners;
- securing of kiwifruit waste and co-substrates;
- selecting a suitable plant location and business case;
- securing of markets for the energy and fertiliser;
- selection of overseas technology partners;
- testing of the anaerobic digestion of kiwifruit in a test-reactor;
- designing the process;
- sourcing of proven technology;
- procurement of technology and components;
- commissioning and training of plant operators.

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Appendix A New Zealand Kiwifruit Production

Appendix A New Zealand Kiwifruit Production by Region

	District	2007 Total Submit Volume (TE)	2007 Total Submit Volume (kg)
1	TE PUKE	8,012,124	29,108,046
2	TE PUKE	5,604,389	20,360,745
3	TE PUKE	5,495,506	19,965,173
4	TE PUKE	5,333,544	19,376,765
5	MT MAUNGANUI	4,887,396	17,755,910
6	KATIKATI	4,759,514	17,291,314
7	EDGECUMBE	3,648,226	13,254,005
8	OPOTIKI	3,155,990	11,465,712
9	TE PUKE	3,032,659	11,017,650
10	KATIKATI	2,983,396	10,838,678
11	MT MAUNGANUI	2,689,975	9,772,679
12	TE PUKE	2,610,082	9,482,428
13	TE PUKE	2,416,116	8,777,749
14	OPOTIKI	2,381,420	8,651,699
15	TE PUKE	2,379,031	8,643,020
16	KATIKATI	2,238,555	8,132,670
17	TE PUKE	1,990,126	7,230,128
18	TAURANGA	1,961,028	7,124,415
19	TE PUKE	1,753,847	6,371,726
20	KATIKATI	1,574,540	5,720,304
21	TE PUKE	1,278,905	4,646,262
22	TE PUKE	1,153,198	4,189,568
23	TE PUKE	1,106,046	4,018,265
24	TE PUKE	1,094,823	3,977,492
25	KATIKATI	951,877	3,458,169
26	TAURANGA	888,957	3,229,581
27	TE PUKE	887,970	3,225,995
28	OPOTIKI	887,815	3,225,432
29	TE PUKE	873,246	3,172,503
30	TE PUKE	844,865	3,069,395
31	KATIKATI	628,098	2,281,880
32	TE PUKE	623,996	2,266,977
33	KATIKATI	613,319	2,228,188
34	TE PUKE	600,318	2,180,955
35	TE PUKE	526,230	1,911,794
36	TE PUKE	518,914	1,885,215
37	GISBORNE	498,379	1,810,611
38	TE PUKE	454,737	1,652,060
39	TE PUKE	434,939	1,580,133
40	TE PUKE	405,087	1,471,681
41	TAURANGA	394,602	1,433,589
43	KATIKATI	331,790	1,205,393
44	WAIHI	258,073	937,579
45	TE PUKE	248,178	901,631
47	TAURANGA	222,082	806,824
48	TE PUKE	137,186	498,397
49	KATIKATI	130,763	475,062
50	EDGECUMBE	128,173	465,653
51	KATIKATI	58,370	212,058
52	TE PUKE	14,411	52,355
	Grand Total	**86,102,811**	312,811,512
	Facility Average	1,722,056	6,256,230

Appendix B Nutritional Data of Kiwifruit

Appendix B Nutritional Data of Kiwifruit

NutritionData Nutrition Facts & Calorie Counter

NutritionData (ND) provides complete nutritional information for any food or recipe, and helps you select foods that best match your dietary needs.

Kiwi fruit, (chinese gooseberries), fresh, raw

Serving size:

Add to Pantry

Email a Friend | Analysis Help

Nutritional Summary for Kiwi fruit, (chinese gooseberries), fresh, raw

Change the serving size in the dropdown above to automatically update the Nutrition Facts label and Nutrient Tables . The remaining elements of this analysis are independent of serving size.

Nutrition Facts

Serving Size 100 grams

Amount Per Serving	
Calories 61	Calories from Fat 4
	% Daily Value*
Total Fat 1g	1%
Saturated Fat 0g	0%
Trans Fat	
Cholesterol 0mg	0%
Sodium 3mg	0%
Total Carbohydrate 15g	5%
Dietary Fiber 3g	12%
Sugars 9g	
Protein 1g	

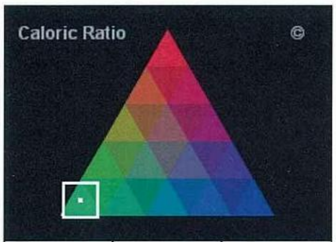
Vitamin A	2%	Vitamin C	155%
Calcium	3%	Iron	2%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

NutritionData.com

Download Printable Label Image

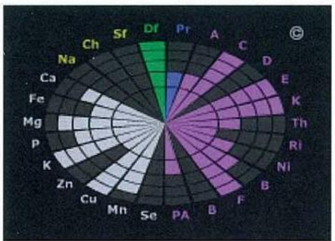
83%
Moisture Content



87%	7%	6%
Carbs	Fats	Protein

Caloric Ratio Pyramid™
This symbol shows how the Calories in this food are distributed between the different macronutrients, and can help you identify foods that best match certain diet plans, such as low-fat, low-carb, high-protein, or balanced-ratio.

Learn more about:
ND's Caloric Ratio Pyramid



55
Completeness Score

Nutrient Balance Indicator™
This symbol illustrates the density of essential nutrients in this food, and can help you create meals that are healthier and more nutritionally balanced.

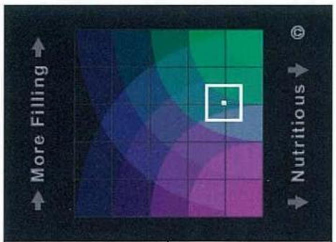
Learn more about:
ND's Nutrient Balance Indicator

ND's Opinion

Weight loss:
Optimum health:
Weight gain:

The Good
This food is very low in Saturated Fat, Cholesterol and Sodium. It is also a good source of Dietary Fiber, Vitamin E (Alpha Tocopherol), Potassium and Copper, and a very good source of Vitamin C and Vitamin K.

The Bad
A large portion of the calories in this food come from sugars.



3.0	4.0
Fullness Factor	ND Rating

Nutritional Target Map™
(Patent Pending)
This symbol maps this food in relation to common nutritional goals. Foods closer to the upper right corner are Better Choices for healthy weight loss, while foods closer to the lower right corner are Better Choices for healthy weight gain.

Learn more about:
ND's Nutritional Target Map
ND's Fullness Factor
ND's Rating
ND's Better Choices Diet

Better Choices Substitutions for Kiwi fruit, (chinese gooseberries), fresh, raw

To explore a list of foods that ND rates higher than this one, select a food category and nutritional goal from the dropdowns and click