Greenhouse
Energy Use &
Carbon Dioxide Emissions

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Executive Summary

AgriLINK New Zealand was commissioned by a multi-stakeholder group comprising MAF, Vegfed and the Energy Efficiency Conservation Authority (EECA) to conduct a pilot survey and scoping report on energy use and carbon dioxide emissions for the heated greenhouse industry. The survey was not representative of the industry but rather captured a range of greenhouse types, fuel types and regional locations.

Statistics are available for the size of the greenhouse industry but these are not separated into heated or unheated, fuel type or greenhouse type. An assumption was made that all greenhouse vegetable production was heated, which covers 250 ha, 56 percent of which is in the Auckland region.

The average energy intensity of the surveyed group was 1,600 MJ/m^2 with a range of between 700 and 2,600 MJ/m^2. An estimate of the industries national energy input is between 2 and 4 PJ.

On a production basis the energy input for the tomato sector, which accounts for 64 percent of the vegetable industry by area, was 38 MJ/kg tomatoes with a range of between 16 to 51 MJ/kg tomatoes.

The energy intensity of double skin plastic greenhouses was approximately half that of single glaze glass. Double glazed glass is not used because of the capital expense and reduced light transmission. While twin skin plastic is more thermally efficient than glass, yields may be less due to lower light levels, particularly as the plastic ages. North Island production was approximately half the energy intensity of the South Island.

On an expenditure basis energy represented 20 percent of operating costs and ranged between 6 – 27 percent.

The average gross carbon dioxide emissions were 125 $kgCO_2/m^2$ and ranged between 35 and 235 $kgCO_2/m^2$. These carbon emissions, at a carbon tax rate of $\$25/tCO_2$, mean an average tax of $\$3.10/m^2$ with a range of \$0.80 to $\$5.90/m^2$. These average survey figures are higher than the likely industry average because of a bias in the survey towards coal users.

On an industry scale the total carbon dioxide emissions ranged between 90 and 590 kt CO_2 per year. The impact of a carbon tax on the industry would be to add \$2.25 million in extra costs, calculated using the lower end of the CO_2 emission range, and a carbon tax rate of $\$25/tCO_2$.

Gaps that were identified for further analysis included improved understanding of both the industry profile and the statistical significance of the indicators. Further analysis is needed into the key variables of greenhouse type, fuel type and location. Several case study energy audits are needed to determine what energy efficiency measures are available and what their likely payback periods would be.

Contents

List of Abbreviations

Energy & Power

J	joule	basic unit of energy
kJ	kilojoule	1,000 joules
MJ	megajoule	1,000,000 joules
GJ	gigajoule	1,000,000,000 joules
TJ	terajoule	1,000,000,000,000 joules
PJ	petajoule	1,000,000,000,000,000 joules
W	watt	basic unit of power = 1 joule per second
kW	kilowatt	1,000 watts
kWh	kilowatt-hour	3.6 MJ/hr

Others

ha	hectare	10,000 square metres
kg	kilogram	
t	tonne	
ℓ	litre	
CO_2	carbon dioxide	
EECA	Energy Efficiency and Conservation Authority	
MAF	Ministry of Agriculture and Forestry	
Vegfed	New Zealand Vegetable and Potato Grower's Federation Inc.	
IPCC	International Panel on Climate Change	
MED	Ministry of Economic Development	

1. Objectives

To develop an industry profile of the indoor greenhouse sector including energy use and identifying gaps in the information compiled. This may form part of a further more detailed study that will be used to factually underpin the presentation of the sectors "at risk" status and subsequent policy development. The further study does not form part of this contract.

Specific objectives include:

- to estimate the size of the sector, both in terms of production, location and energy use;
- to assess energy types used;
- to estimate the intensity of energy use relative to physical production;
- to assess the potential for energy efficiency improvement within the sector and areas where further investigative work could be undertaken, including uptake of new technologies and barriers to change;
- to calculate an indicative estimate of emissions units produced by the sector, including taking into account carbon dioxide recycled within the greenhouse systems.

This is intended to be a scoping study only and that these objectives are based on the information being readily available.

2. Methodology

The data for this study was collected from a selection of 12 greenhouse operations from around New Zealand using a concise survey form that was mailed to growers and then followed up with a face to face interview. A copy of the survey form is attached as Appendix 1.

The survey participants were selected on the basis of getting a range of different greenhouse types, fuel sources and regional locations. As a result the survey is not representative of the industry.

Tomato production was the predominant operation surveyed but others also included cucumber, capsicum, aubergines and roses. The predominant cropping structure was glass with some double skin plastic greenhouses also represented.

The total direct energy use and carbon dioxide emissions associated with each operation was calculated using energy coefficients and carbon emission factors derived from national and international data.

2.1 BOUNDARY DEFINITION

The boundaries for this study were defined as the physical boundaries of a greenhouse operation. This meant that only that energy supplied directly to the operation, e.g. heating fuels and electricity were considered. This excluded transport and packing shed operations that were carried out off the property.

While these activities will also attract a carbon tax, the energy component in these activities is beyond the scope of this study. Other indirect energy inputs such as fertiliser and agri-chemicals have energy embodied in them and will also attract a carbon tax via their manufacturing, transport and packaging, but again this was beyond the scope of this study.

2.2 CONSUMER VS. PRIMARY ENERGY

Energy use has been based on consumer energy or the energy directly delivered to the operation i.e. the kilowatt-hours as read at the meter. Primary energy includes both the consumer energy and all the energy required to get that energy to the consumer. This additional energy includes that energy expended or lost during processes such as extraction, refining, generation, conversion, transportation and distribution.

Some energy studies use primary energy as they want to account for the total energy input into a system, from both direct and indirect sources. In this study however we have used consumer energy in order to avoid double counting in the supply chain and because it is assumed that this is the point at which a carbon tax would be applied.

2.3 ENERGY AND CARBON CONTENT

The direct energy inputs into a growing system are heating fuels, predominantly gas or coal, and electricity for operating motors and lights. Other minor direct inputs are diesel, petrol and lubricants, predominantly for transport, although these were excluded from the total energy use as discussed in Section 2.5.

There is considerable variation in the carbon and energy content by weight of fuels. However, expressing the carbon emission factor as the carbon content per unit of energy released reduces this variation because of the close link between the carbon content and energy value of fuel (IPCC, 1996). Different coal types are a good example of this and are discussed in Section 3.6.

Carbon dioxide emissions are primarily dependent on the carbon content of fuel. Due to the molecular weight ratio of carbon dioxide to carbon of 44:12, multiplying the weight of carbon by 3.6666 gives the quantity of carbon dioxide omitted when the carbon is oxidised.

Energy and carbon data for all commercial fuels is available from both domestic and international databases. However, because fuel qualities and emission factors may differ markedly between countries, IPCC recommends that inventories should be prepared using local emission factors and energy data where possible. Table 1 shows the energy and carbon values for each fuel type included in the study and references where these figures were sourced.

Table 1. Energy and Carbon Values

Fuel	Energy	Units	Carbon (g/MJ)	CO_2 (g/MJ)
Coal (sub-bituminous)	21.1 [a]	MJ/kg	24.9 [b]	91.2
Waste oil	38.7 [a]	MJ/ℓ	20.1 [b]	73.7
Gas	3.6	MJ/kWh	14.3 [b]	52.3
Electricity	3.6	MJ/kWh	11.8 [c]	43.1

Data source:
[a] NZ Energy Data File July 2002 (MED)
[b] NZ Greenhouse Gas Emissions 1990-2001
[c] Per comm. Ted Jamieson EECA, 2003

2.3.1 Coal (sub-bituminous)

All coal use was collected in the survey as tonnes used per year. This was converted into an energy value using the coefficient for coal of 21.1 MJ/kg based on MED data for New Zealand's sub-bituminous coal (NZ Energy Data File, July 2002). Growers were not asked for the coal type(s) that they were using so in the absence of this information it was assumed that all coal was sub-bituminous. This is consistent with the approach taken by MED when calculating greenhouse gas emissions (NZ Energy Greenhouse Gas Emissions 1990-2001). Any further study should determine the mix of coal types being used.

The carbon content of 24.9 gC/MJ is calculated from the emission factor of 91.2 kt CO_2/PJ (NZ Energy Greenhouse Gas Emissions 1990-2001).

2.3.2 Waste Oil

Waste oil was recorded on the survey form as litres per annum. This was converted into an energy value based on the average calorific value of light and heavy fuel oil of 38.7 MJ/ℓ (NZ Energy Data File, July 2002).

The carbon content of 20.1 gC/MJ is calculated from fuel oil having a carbon dioxide emission factor of 73.7 kt CO_2/PJ (NZ Energy Greenhouse Gas Emissions 1990-2001).

2.3.3 Natural Gas

All gas use was collected in the survey as either GJ or kWh from meter readings on supply company invoices that were twelve months apart.

The carbon content for gas of 14.3 gC/MJ is the average emission factor for distributed gas in 2001 (NZ Energy Greenhouse Gas Emissions 1990-2001).

2.3.4 Electricity

Electricity was collected in the survey as kWh from meter readings on supply company invoices that were twelve months apart.

The carbon content of 11.8 gC/MJ was calculated using an average for the grid of 0.155 tCO_2/MWh (43.06 gCO_2/MJ). This figure has not changed much over the last ten years and is expected to range from 0.14 to 0.17 tCO_2/MWh (per comm. Ted Jamieson EECA, 2003)

2.4 CARBON TAX

The carbon tax is based on the rate of $25/t CO_2. The Government has indicated that the emissions charge is to be set at the world price but capped at $25/t.

2.5 TRANSPORT

To be consistent with the boundary definition, fuel used for transport off the property, either by a contractor or the operator, is excluded. It was not possible to allocate that fraction of fuel which was just used on the property versus transport off the property and as this would be insignificant all diesel, petrol and lubricants were excluded form the total energy use.

Growers were asked for the quantity of fuel used for their own transport in order to assess how big a component of energy use this was. Of those growers who were able to respond, fuel use for transport (excluding contractors) accounted for less than 2 percent of their total energy use.

2.6 INDIRECT INPUTS

Inputs such as fertiliser and agri-chemicals have energy embodied in them as a result of their extraction, manufacture, transport, and distribution. These are considered indirect energy inputs and while their New Zealand manufacturers are likely to be affected by a carbon tax, the potential cost to an operation has not been calculated in this study.

2.7 ENERGY ANALYSIS

2.7.1 Energy Intensity per m^2

Energy intensity for each of the twelve operations surveyed was calculated by dividing the total energy input for each operation by its heated area. These figures were averaged to calculate the energy intensity indicator for the industry. An estimate of the industry's total energy use was calculated by multiplying the average energy intensity by the sector's total area.

A separate analysis of the energy intensity for the two main fuel types, coal and gas, has not been included, as energy intensity is predominantly determined by the greenhouse cladding material, inside temperature regime and outside air temperature, rather than the fuel type. The fuel type has an impact on the carbon indicators, and hence the carbon tax, but not on the energy intensity.

A comparison was made between greenhouse types and North and South Island differences. These figures are indicative only as three of the four categories had only one or two growers.

2.7.2 Energy Input per Yield

One method of analysing the energy input into a greenhouse operation is to base it on energy input per yield rather than per square meter.

The range of crops grown by the greenhouse operations in the pilot study included tomatoes, cucumbers, capsicums, aubergines and roses. However, due to the small sample size an analysis of the energy input based on yields could only be performed for the tomato sector, which was the largest sector represented.

The energy analysis based on yields was restricted to the operations that grew tomatoes exclusively. Where an operation grew a combination of crops they were removed from the energy input per yield calculation as it was not possible to attribute the quantity of energy used for the different crops. Six operations were included in this analysis. All operations were included in the energy intensity per square meter calculations.

2.8 CARBON ANALYSIS

Gross carbon dioxide emissions were calculated using the carbon coefficients described in Sections 2.3.1 to 2.3.4. Like the energy indicators these were expressed on both a square meter and yield basis.

A comparison was made of the gross carbon dioxide emissions between coal and gas users. Relevant comparisons can only be made when the variation caused by greenhouse cladding and regional location is removed. In the pilot survey only three operations could be compared in this way. One operation used coal and gas in different glasshouses, although one glasshouse was older than the other. The other two operations were North Island glasshouses each using a coal or gas fired heater.

3. Results

3.1 INDUSTRY PROFILE

There are no official statistics for the total area of heated greenhouses in New Zealand.

The estimates of industry size in the most recent comprehensive horticultural survey by the Department of Statistics for the year ending June 2000 is for greenhouse cropping area. There is no distinction made between heated and unheated greenhouses.

In the absence of more accurate figures it has been assumed that all greenhouse vegetable crops are heated. No attempt has been made to estimate the size of the heated nursery or flower industry although the areas would be relatively small compared to the total size of the respective industries.

There are approximately 250 ha of heated greenhouse vegetable production in New Zealand, 200 ha in the North Island and 50 ha in the South Island.

There are a wide range of greenhouse types including glass, single and twin skin plastic. The type of structure and their age has a large influence on the thermal characteristics. No information is available on the area covered by each greenhouse type. The more thermally efficient twin skin plastic houses have lower light levels, than glass, particularly as the plastic ages, which can reduce yields.

Table 2 shows the regional distribution of greenhouse crops. Of the total area in greenhouse vegetable crops, 79 percent are grown in the North Island, and approximately 68 percent[1] are grown in the Auckland region alone.

In the South Island 50 percent[2] of the vegetable production comes from the Canterbury region which represents 10 percent of the New Zealand crop.

Throughout New Zealand, tomato production accounts for 64 percent of the vegetable crop, with cucumbers and capsicums representing 20 percent and 16 percent respectively. Other minor crops such as aubergines were not included in the statistics.

The distribution of greenhouse tomato production area is:

Auckland	56%
Canterbury	12%
Waikato	7%
Tasman	5%
Northland	4%

The remaining 16 percent is scattered around New Zealand.

Flower production has the same greenhouse area as vegetables, 250 ha, however while most of the vegetable production is heated only a small proportion of flower growers use heat. Those flower growers that do heat, for example many rose growers, use similar heating regimes to vegetable producers.

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[1] Assumes 70% of the NI capsicum crop is grown in Auckland. The exact figure has been suppressed for confidentiality reasons.
[2] Assumes 60% of the SI capsicum crop is grown in Canterbury. The exact figure has been suppressed for confidentiality reasons.

The greenhouse nursery industry at approximately 100 ha in total, would only have a small fraction of growers that use heating.

Table 2. Area in Indoor Crops Harvested by Regional Council During the Year Ended 30 June 2000

Regional Council	Tomatoes	Capsicum	Cucumber	Nursery Crops	Flowers	Mushrooms
	Square Meters					
Northland Region	62,607	C	57,944	38,246	304,445	C
Auckland Region	893,241	C	246,132	455,338	1,034,878	C
Waikato Region	111,579	26,273	C	17,154	310,132	C
Bay of Plenty Region	28,729	26,931	C	35,858	C	C
Gisborne Region	C	C	C	33,596	C	0
Hawke's Bay Region	36,035	8,196	C	57,290	39,353	C
Taranaki Region	C	C	15,616	8,892	78,558	0
Manawatu-Wanganui Region	29,816	4,381	C	49,267	185,383	C
Wellington Region	28,489	C	5,484	37,781	23,042	C
Total North Island	1,205,928	365,296	421,902	733,420	2,178,472	216,257
Tasman Region	86,061	14,065	14,098	40,082	30,522	0
Nelson Region	31,732	C	C	C	C	0
Marlborough Region	61,231	2,640	C	4,170	25,649	C
Canterbury Region	189,957	C	51,399	125,445	205,194	C
Otago Region	13,214	C	C	71,246	28,016	C
Southland Region	C	C	C	18,370	5,527	0
Total South Island	396,020	49,252	77,132	259,413	306,254	190,130
Total New Zealand	1,601,948	414,548	499,034	992,833	2,484,726	406,387

Source: Department of Statistics Horticultural Production Survey for the year ending June 2000
C - Data suppressed for confidentiality reasons.

Table 3. Number of Indoor Vegetable Growers by Regional Council During 2002

Regional Council	Tomatoes	Capsicum	Cucumber
Northland Region	29	16	18
Auckland Region	237	31	53
Waikato Region	15	3	2
Bay of Plenty Region	18	5	4
Gisborne Region	7	0	0
Hawke's Bay Region	29	8	4
Taranaki Region	3	1	4
Manawatu - Wanganui Region	12	3	3
Wellington Region	40	6	8
Total North Island	390	73	96
Tasman Region	-	-	-
Nelson Region	35	6	13
Marlborough Region	8	2	5
Canterbury Region	62	13	14
Otago Region	15	3	4
Southland Region	7	0	2
Total South Island	1415	24	38
Total New Zealand	517	97	134

Source: Vegfed

Table 3 gives the distribution of growers, although they can be counted more than once if they grow a couple of different crops. The industry trend is for the number of operations to reduce and the average size to increase. While it is not possible to accurately gauge the recent change in productive area it is the opinion of Vegfed (pers. comm. Tony Ivicevich) that the productive area has remained relatively constant and that this is likely to remain the same in the foreseeable future unless a significant and consistent export market is found. Significant areas that have been constructed recently have been offset by smaller growers exiting the industry.

3.2 GROWER SAMPLE PROFILE

The survey was biased towards coal users which made up nine of the twelve surveyed. Two of the nine coal users also used gas and a further two used gas exclusively. One grower used waste oil for heating. Seven of the growers were in South Auckland or further north, one was in Tasman and four were in Canterbury or Otago.

3.3 PRODUCTION PROFILE

Table 4. Production per Operation

Indicator	Average Surveyed	Range	NZ Average*
Vegetable production area (m^2)	34,700	2,700 – 201,000	3,400
Tomato production area (m^2)	9,400**	2,800 – 32,000**	3,100
Tomato yield (kg/m^2)	43	30 - 50	42

* Some double counting of growers makes these figures lower than the true value.
** Those growing two or more crops were excluded as the survey did not ask for the specific area of each crop.

3.4 ENERGY PROFILE

3.4.1 Grower Operation Level

The annual total energy input (excluding solar) into a greenhouse system can either be expressed as energy intensity in MJ/m^2 or by incorporating the operation's productive output it can be expressed as energy input in MJ/kg output.

The average energy indicators for the surveyed operations are shown in Table 5. This is not representative of the industry as the pilot survey was very small and growers were selected on the basis of obtaining a range of different greenhouse types, fuel sources and regional locations.

Table 5. Energy Indicators

Indicator	Average	Range
Total Energy Intensity (MJ/m^2)	1,600	700 – 2,600
Energy Input (MJ/kg_{tomato})	38	16 – 51

Table 6. Energy Intensity by Region and Greenhouse Type

Region	Glass (MJ/m^2)	Double Plastic (MJ/m^2)
North Island	1,600	700*
South Island	2,100*	1,600*

* Two or less growers in this category

Some of the variation shown in the energy indicators can be explained by the type of greenhouse and its regional location. Table 6 gives an indication of the difference both between the North and South Island and glass versus double skin plastic. Due to the extremely small sample size these figures need to be viewed with some caution. However they do show what you would expect, namely that South Island production is more energy intensive than in the North Island and that glass cladding is more energy intensive than double skin plastic.

3.4.2 National Level

Extrapolating the results from this pilot survey to estimate the total energy size of the greenhouse industry must be viewed with caution as the survey was not representative, see Methodology Section 2.0. Not only was the survey not representative but there is uncertainty about the heated area, as well as greenhouse cladding type of heated greenhouses.

Assuming an estimated heated greenhouse area of 250 ha the national energy use for greenhouse vegetable production is between 2 and 7 PJ. As a best estimate the likely national energy use figure will be between 2 and 4 PJ.

It is possible to calculate the national energy use for the tomato sector based on production. The annual production of standard loose round tomatoes is approx 35,000 tonnes (per. comm. Ken Robertson, Vegfed) as a result the energy input will range between 0.6 to 1.8 PJ, with an average of 1.3 PJ. It is necessary to add to this the energy input from the unknown quantity of specialty tomatoes; e.g. cherry tomatoes, small and medium plum tomatoes, tomatoes on the vine plus the other greenhouse vegetables including cucumbers and capsicums which represent approximately 36 percent of the industry by size.

The national energy demand for the 'agriculture and hunting' sector is 12.1 PJ (Energy Data File Jan. 2002). This figure underestimates the actual use as it does not include gas which is unallocated for the different agricultural and industrial sectors.

However, if it is assumed that 12.1 PJ represents the national energy demand for agriculture and hunting, 2 PJ represents 17 percent of the national agricultural energy demand.

3.5 CARBON PROFILE

3.5.1 Grower Operation Level

Gross carbon dioxide emissions of the surveyed operations averaged 125 $kgCO_2/m^2$. On the tomato operations the average gross carbon emissions were 3.1 $kgCO_2$/kg tomato. Like the energy indicators, the carbon indicators have a large range reflecting the type of greenhouses and their regional location.

Table 7. Carbon Indicators

Indicator	Average	Range
Gross CO_2 Emissions ($kgCO_2/m^2$)	125	35 – 235
Gross CO_2 Emissions ($kgCO_2/kg_{tomato}$)	3.1	0.8 – 4.7

Table 8. Carbon Emissions and Tax (Surveyed Operations)

	Average	Range
Annual Tonnes CO_2 per operation	3,500	130 – 21,800
Annual Carbon Tax ($\$/m^2$)	3.10	0.80 – 5.90
Annual Carbon Tax per operation ($)	88,400	3,400 – 544,000

Table 9. Carbon Emissions and Tax (NZ's average sized operation)

	Average	Range
NZ's Average Size Operation (m^2)	3,400	
Annual Tonnes CO_2 per operation	420	110 – 800
Annual Carbon Tax per operation ($)	10,500	2,900 – 19,900

3.5.2 National Level

On a national basis the gross carbon dioxide emissions from the greenhouse vegetable industry range between 90 and 590 $ktCO_2$ with a mean of 310 $ktCO_2$. These figures are likely to over estimate the true national figure because of the survey bias towards coal users. The uncertainty over the industry's size and type of greenhouses adds further potential error to the estimate of gross emissions. Even at the low end of the range a carbon tax will add another $2.25 million dollars worth of costs to the industry. Ninety ktCO_2 is 7 percent of the agricultural sector's carbon dioxide emissions in 2001 (NZ Greenhouse Gas Emissions 1990 – 2001).

See Section 3.4.2 for a discussion on the accuracy of extrapolating these figures.

3.5.3 Net Carbon Emissions

Under the Kyoto Protocol New Zealand has to reduce its emissions to 1990 levels or take responsibility for any excess emissions. New Zealand's assigned amount is 365 million tonnes of carbon dioxide equivalent for the first commitment period. Carbon sink credits will help the Government achieve that goal. Afforestation is counted as a carbon credit because carbon sequestered in forests is considered "permanent" under the protocol, but carbon tied up in other crops for example, tomatoes and tomato plants, would not be counted as a credit under Kyoto because it is released within a year of being sequestered. **Net** emissions from the greenhouse sector (or any other non-forestry sector) are not therefore relevant in meeting the requirements of the Kyoto protocol.

3.5.4 Carbon Tax

Table 10 shows the effect of a carbon tax, at a rate of $25/t$CO_2$ on each fuel source considered in this study. Sub-bituminous coal has a carbon tax of 4.8 cents per kilogram or $48 per tonne.

Table 10. Carbon Tax by Fuel Type

Fuel	Units	C O_2 (kg/unit)	Carbon Tax (¢/unit)
Coal (sub-bituminous)	kg	1.92	4.81
Waste oil	ℓ	2.85	7.13
Gas	kWh	0.19	0.47
Electricity	kWh	0.16	0.39

Table 11. Energy Intensity, Carbon Emissions and Tax by Fuel Type

Description	Energy Intensity (MJ/m^2)	Carbon Emissions (kgCO_2/m^2)	Carbon Tax ($/$m^2$)
North Island Glass and Coal $_{\text{grower 1}}$	1,200	110	2.70
North Island Glass and Gas $_{\text{grower 1}}$	2,100	110	2.70
North Island Glass and Coal $_{\text{grower 2}}$	1,400	130	3.10
North Island Glass and Gas $_{\text{grower 3}}$	1,400	80	1.90

Table 11 illustrates that given the same energy intensity a coal fired operation can expect to pay approximately 60 percent more carbon tax than a gas fired user. As a consequence of the survey being biased towards coal users the average carbon tax of $3.10/$m^2$ is probably an over estimate for the industry. Although it must also be remembered that one grower in the survey would pay a carbon tax of $5.90/$m^2$.

3.6 COAL TYPE

Both the energy value and carbon content of coal varies considerably depending on the type of coal. There are three main coal types lignite, sub-bituminous, and bituminous. Even within these coal types there are variations depending on the region and mine. Assuming average figures for each coal type (MED, 2002) the effect on the carbon tax can be seen in Table 12.

Table 12. Carbon Content and Tax by Coal Type

Coal Types	Energy (MJ/kg)	Carbon Content (gC/MJ)	CO_2 ($kgCO_2$/MJ)	CO_2 ($kgCO_2/kg_{coal}$)	Carbon Tax (¢/kg)	Carbon Tax ($/t)	Carbon Tax (¢/MJ)
Lignite	14.1	27.6 [a]	0.101	1.43	3.57	35.67	0.25
Sub-bituminous	21.1	26.2 [b]	0.091	1.92	4.81	48.11	0.23
Bituminous	28.6	25.8 [a]	0.095	2.71	6.76	67.64	0.24

Data source:
[a] IPCC, 1996
[b] NZ Greenhouse Gas Emissions 1990-2001

Despite bituminous coal being almost double the tax cost per tonne compared to lignite coal, the higher energy content of bituminous coal means that on an energy content basis the carbon tax cost is very similar.

In the pilot survey the growers using coal for heating were asked for the annual quantity in tonnes. The survey did not ask what type of coal they were burning. To calculate total energy use for each operation, the assumption was made that the coal was sub-bituminous. Where this was not the case the total energy input in the system will be over or under estimated as shown in Table 12. As a consequence the carbon content will also be over or under estimated. Any follow up work needs to determine the coal types that are being used.

3.7 EXPENDITURE

Operating costs average $47/m^2 and ranged between $33/m^2 and $86/m^2. The list of inputs that made up the operating costs is shown in the survey form, Appendix 1.

Grading/packing/marketing was collected but not included in the total operating costs above. This follows the model used in the analysis of “on-farm” energy inputs in a dairy farm (Wells, 2001), in which Fonterra’s costs of manufacture, packaging and marketing were not included. Repairs and maintenance was also excluded as they were considered a component of fixed costs. Diesel, petrol and lubricants while being an operating cost were also removed in order to be consistent with the energy analysis, see Section 2.5. These fuels made up less than 1 percent of expenditure.

The largest component of operating costs is wages, which ranged between 18 percent and 54 percent, with a mean of 37 percent. The second largest component is energy ranging between 6 percent and 27 percent, with a mean of 20 percent.

4. Information Gaps and Areas of Further Analysis

The aim of this project was to conduct a pilot survey into energy use in the greenhouse sector and prepare a report describing the energy and carbon indicators, assess the potential for energy efficiency improvements and identify information gaps.

There is considerable variation in the energy and carbon indicators. Some of this variation can be explained by greenhouse type and location. A larger sample of operations needs to be surveyed to enable indicators with better statistical significance to be developed. Further analysis is needed on the key variables of greenhouse cladding, coal type and location.

One of the factors that is causing uncertainty when determining the national energy use was insufficient data on the area of heated greenhouses, and just as importantly the area and regional distribution of different greenhouse types. This needs to be improved through a grower survey.

When conducting the surveys it became apparent that grower knowledge about the impacts that the Kyoto Protocol will have ranged from very little understanding to considerable understanding and concern. There is a need to improve general grower awareness of the potential impacts. This could initially involve improving grower awareness based on what information is already available. However, there is also the need to improve our confidence in the figures and implications before progressing too far with whatever course of action is chosen.

When we have greater confidence in the data regional models should be developed to show the impact of different greenhouse types and heating strategies.

The issue of net carbon dioxide emissions needs to be properly explained to the industry or else it may became an obstacle to a continued cooperative approach.

An economic analysis is needed into the impact that a carbon tax will have on the industry's domestic and export profitability, including import substitution from non signatory countries to the Kyoto Protocol such as Australia. Greenhouse operations are labour intensive, so any economic analysis should incorporate the social impacts of reduced competitiveness.

It was not possible to adequately investigate energy efficiency improvements. This could be achieved by conducting several energy audits that can identify efficiency improvements and calculated the payback periods.

There has been some discussion amongst growers about using alternative renewable energy sources, such as biomass furnaces. This needs further investigation.

This project investigated the direct energy costs, but the effects of a carbon tax will be felt throughout the supply chain including grading, packing, transport and inputs with high levels of embodied energy like nitrogen fertiliser. The scope of any follow up report needs to be widened to include these indirect energy inputs.

5. References

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Appendix 1 – Survey Form

Greenhouse Energy Survey (2001/2002)

Date of survey: ………………….. Interviewer: ……………………
Operation: ………………………..

1 General

1.1	Region	……………………….
1.2	Total area under cover (m^2)	……………………….
1.3	Total heated area (m^2)	……………………….
1.4	Greenhouse material (glass / single or double plastic)	……………………….
1.5	Greenhouse age	……………………….
1.6	Greenhouse height to gutter	……………………….

2 Production

2.1	Crop type and area	……………………….
2.2	Yield (e.g. $kg/m^2/yr$)	……………………….
2.3	Crop type	……………………….
2.4	Yield (e.g. $kg/m^2/yr$)	……………………….
2.5	Crop type	……………………….
2.6	Yield (e.g. $kg/m^2/yr$)	……………………….

3 Cash Farm Expenditure

The intention is to have an accurate estimate of energy costs as a fraction of the total cost of production. Add any other major costs to the list below. Electricity and heating costs are accounted for in Section 4. Note what the dollar costs are per e.g. year, or m^2.

Variable Expenses	**$ / …….**
Wages permanent	
casual	
Transplants	
Growing media	
Fertiliser	
Fungicide	
Insecticide	
Herbicide	
(or Total Agrichemical)	
Pollination (bumblebees)	
Clips and training twine	
Market box's	
Grading/packaging/marketing	
Repairs and maintenance	
Rates	
Water Charges (Irrigation)	
Communication Costs (phone & mail)	
Insurance	
Accountancy	
Legal & Consultancy	
Other Admin	
Other Expenditure	

4 Direct Energy Use (2001/2002)

Heating - Fuel Purchases

4.1 What is the heating source ……………………….
(e.g. gas/coal/other)

It is important to know the total units/year (column 1). If you can only reply in dollars please give an indication of the average price per unit and whether or not GST and line charges are included or excluded. Only complete the electricity section if it is your heating source.

A copy of your latest monthly account would be very helpful

		Total units/year (kW, tonnes, litres)	Avg $ per unit	Total dollars
4.2	Gas			
4.3	Coal			
4.4	Diesel			
4.5	Electricity			
4.6	Other			

Line or delivery charges for the above heating source

4.7	Description	Rate	Total dollars
4.8	Fixed charge		
4.9	Variable charge		
4.10	Meter charge		
4.11	Delivery charge		
4.12	Other charge		

4.13 Was last year typical? Yes / No
If you answered No

4.14 As a percentage, by approximately how much higher or lower would your heating usually be? (e.g. 10% higher) …………………………………

4.15 What is the design heating point?
day ……………………….
night ……………………….

General Energy Use - Electricity Purchases

It is important to know the total units/year (column 1). If you can only reply in dollars please give an indication of the average price per unit and whether or not GST and line charges are included or excluded.

A copy of your latest monthly account would be very helpful

		Units/yr (kWh)	Avg $ per kWh	Total dollars
4.16	Greenhouse (fans/lighting/motors/pumps)			
4.17	Cool store			
4.18	Irrigation bore			
4.19	Packing shed			
4.20	Other			

Exclude domestic dwellings

Electricity line charges

4.21	Description	Rate	Total dollars
4.22	Fixed charge		
4.23	Variable charge		
4.24	Meter charge		
4.25	Other charge		

Transport - Fuel Purchases

		Litres	Dollars	Avg $ per litre
4.26	Diesel			
4.27	Petrol			
4.28	Lubricants			

Exclude domestic vehicles

4.29 Do you use contractors to transport your produce to market? Yes / No

5 CO_2 Use

5.1 Do you circulate CO_2 in the greenhouse? Yes / No

5.2 If YES – what is the source? Bottled / Captured flue gases / Burn

5.3 What quantity of CO_2 do you use? ……………………….

Appendix 2 – Net Carbon Emissions

Carbon is exported off the operation either sequestered in the fruit or plant material. This can be accounted for in the Net Carbon Emissions which is calculated by subtracting the carbon locked up in the crop and plant material that is exported out of the system from the carbon imported into the system through energy use.

The carbon content of a crop can be determined by multiplying the dry weight of the organic substances by its carbon content. The typical energy and carbon content of different organic substances is shown in Table A1 (Holland et al, 1991).

Table A1 Energy and Carbon Content of Organic Substances

Organic Substance	Energy Content (MJ/kg)	Carbon Content (% weight basis)
Fats	37	70
Proteins	17	46
Carbohydrates	16	40
Minerals	2	0

Table A2 Energy and Organic Substance Content of Tomatoes per 100g

Water (g)	Fats (g)	Proteins (g)	Carbohydrates (g)	Carbon Content (g)
93.76	0.33	0.85	4.64	2.48

From the typical energy and carbon contents of organic substances given in Table A1 and the composition of tomatoes, Table A2 (USDA and ARS, 2003) it can be estimated that tomato fruit typically contain 24.8 grams of carbon or per kg of fruit, which equals 90.9 grams of carbon dioxide.