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Understanding Victoria's Fruit and Vegetable Freight Movements – Executive Summary

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1. Executive Summary

Context

This report outlines the methodology and results of Part 2 of a three-part project initiated by the Victorian Eco-Innovation Lab (VEIL), which aimed to shed light on greenhouse gas emissions and vulnerabilities in Victoria's food freight systems.

The operations of the food industry can transform agricultural raw materials into safe, convenient, good tasting and nutritious products for consumers. However, to continue profitably doing so, it is becoming increasingly important to be more environmentally sustainable (particularly in terms of GHG emissions) and resilient to a changing agricultural landscape, oil price fluctuations, markets and weather variability.

While the greenhouse emissions from agriculture (12.9% of Victoria's total emissions) are increasingly well understood, emissions generated throughout the supply chain are considerably less so. Post-farmgate activities include packaging, processing, transport, storage, retail etc. These supply chains are complex and variable. A summary of existing knowledge is contained within this report and that from Part 3 of the project.

The horticulture industry in Australia is valued at $3.5 billion and in Victoria is worth $1.3 billion per annum. An improved understanding of the factors affecting greenhouse emissions, fuel use and potential vulnerabilities in the supply chains of these products will be important to their ongoing viability.

The analysis outlined in this report is intended to contribute to an increased understanding of how fruit and vegetables are moved from production to consumers in Victoria and the greenhouse emissions implications of this operation. The analysis is focused only on the ***transport*** components of the supply chain, including refrigeration within transport where required, but it ***does not*** include energy use of emissions from production, processing, packaging etc. It should not be understood as a lifecycle analysis, it is intended only to increase understanding regarding the transport components of food (particularly fruit and vegetable) supply chains in Victoria.

Development of Methodologies

The key elements required in this analysis were identified as:

- Mapping of fruit and vegetable supply chains in Victoria, identifying: sources and destinations; transport types and amounts; key features (*e.g.* bottle-necks)
- Analysing greenhouse gas emissions throughout these supply chains i.e.
  - What are the contributions of different components of the fruit and vegetable supply chains to greenhouse gas emissions;
  - Identifying how these supply chains vary throughout the year, according to seasons and conditions; and
  - Exploring relative contributions to greenhouse gas emissions of changes in these components.

Two complementary methodologies have been developed and used for exploration of different components.

The first, described in Part A, employed a deterministic approach to the analysis. This approach allowed the study to identify and assign suitable values (observed or estimated) for each set of variables representing the required components of the supply chain. It approximates and makes assumptions as appropriate, to enable calculation of summary values and overall measures of efficiency in the system.

The second type of analysis, described in Part B, explored the sensitivity of total greenhouse gas emissions to changes in different variables i.e. the relative significance of different components in the supply chain. Although some initial sensitivity analysis was undertaken using the methodology developed in Part A, the high level of data uncertainty and the need to investigate a large number of iterations of variables to represent reasonable scenarios made further pursuit of this approach infeasible within the scope of this project.

To overcome the high levels of uncertainty, a second analysis tool based on 'stochastic modelling' (which can take account of the probabilities of different events), was developed, to enable evaluation of the sensitivity of greenhouse gas emissions to a wide range of variables.

These two methodologies are summarised below and outlined in more detail in the full report and appendices.

Part A: Deterministic Analysis

To conduct the deterministic analysis, a large amount of data was gathered to map the Victorian supply chain of fruit and vegetables (F&V) and therefore assess likely transport requirements. The food movements investigated in this project included:

- Movements of fresh and processed F&V produced and consumed in Victoria.
- Movements of fresh F&V produced external to Victoria and consumed in Victoria (interstate and international);
- Movements of fresh F&V produced in Victoria and consumed externally (not including international transport legs).

This required information on the locations and amount of produce:

- Produced and moved from different NRM regions in Victoria;
- Movement of produce between states and internationally;
- Major processing centres;
- Distribution centres and Melbourne Markets;
- Retail outlets – major supermarket chains, independents and grocery stores; and
- Census collection districts where the population of consumers are sourced.

Once the amounts of produce and estimated pathways had been determined, a range of other factors affecting greenhouse gas emissions were also taken into account. These include:

- Vehicle types: articulated, rigid and light commercial (LCV);
- Proportion of trips refrigerated;
- Forward and backhaul trips; and
- Payloads – amount of produce moved within trip.

There have been very limited studies that map out Australian food freight movements across the complex landscape between production and consumer, let alone with the purpose of evaluating GHG emissions. Data availability on aspects such as volumes traded between states, volumes traded through specific supermarket chains and Melbourne Markets, and consumption of fresh and processed F&V was by far the greatest limitation in this project. Data of this type was either not collected historically due to the large volumes of information, or it is highly confidential information not publicly available. This project must therefore be interpreted in the context of these data limitations.

To map out the F&V supply chains, raw data was gathered from multiple sources, including the Australian Bureau of Statistics (ABS), information from the Department of Primary Industries Victoria, Geographical Information Systems databases, market research published by IBISWorld and several others. Where data gaps existed, various methods of inference were used to estimate these flows. These methods are described in the report.

To take account of all these variables, a MS Access-based model, hereafter known as the Supply Chain Database Tool (SCDT), was developed. This model consists of Access queries performed on Excel input tables to obtain estimates of emissions produced by the transport and distribution of F&V in Victoria. The development of this tool was crucial in detaching the modelling work from the uncertainties in the data collection effort, as it enables various combinations of parameters and input tables to define different scenarios.

Due to the uncertainties in data collection, the SCDT enables investigation of relative (rather than absolute) measures of emissions, indicating the emissions produced from a base scenario based on one set of average values (*e.g.* average payload, average emissions factors, average distance). The emissions estimates from the supply chain legs for this base scenario were then aggregated into a range of categories to enable comparison i.e. relative contributions of different system attributes (see 1.3.1).

Full details of the deterministic methodology and assumptions are contained in the report. Appendix A provides a technical description of the database tool and an overview of how to use the Supply Chain Database Tool.

Assumptions are noted throughout the report in cases where data has been a limitation. The analyses and models created from this project should be treated as living documents, which improve as further accurate information is incorporated.

Part B: Sensitivity Analysis

The first part of the sensitivity analysis was conducted by varying input data in the SCDT to explore the impact of changing truck sizes on emissions. However, in light of the significant data uncertainties, fuller exploration of the wide range of variables and uncertainties would require a very large number of iterations, which could not be completed within the scope of this project (see Research Extensions).

A second analysis tool, based on stochastic modelling, was developed to enable sensitivity analysis to be conducted on a wide range of variables within the timeframe and budget of this project.

For the purposes of identifying the major factors affecting GHG emissions in Victorian F&V chains, major supermarket chains (MSC) and Melbourne Markets-greengrocer chains (MM) were considered to be largely representative of current marketing methods (they cumulatively account for 97% of the total F&V trade[1]). Further, only fresh F&V product entering the Victorian market (through state production, imports and interstate trade) was considered. Time and scope limitations meant that exports and F&V volumes leaving Victoria could not be considered within this analysis.

Table 1.1 summarises how the use of this different tool has enabled a range of values for each variable to be considered, by comparing the input data for a number of key emissions contributors.

[1] The remaining trade is attributable to a wide variety of small grower-consumer channels, amply discussed by Estrada-Flores and Larsen (2010).

Table 1.1: Comparison of Assumptions in Deterministic and Stochastic Models

Assumption	Deterministic	Stochastic
Vehicle types per segment	Constant mix of vehicles (LCV, rigid trucks, articulated trucks)	Mix of vehicles (LCV, rigid 2 axles, rigid 3-axles, articulated long haul and articulated B-double)
Payload per vehicle type	One load capacity (average payload)	Different loading capacities between a minimum and the maximum capacity per vehicle
Fuel consumption	Constant – independent of load	Variable and dependent on loading capacity used.
Backload per segment	Constant	Variable
Emissions from ship (imported product)	Calculated as per road analysis, with constant emission factors	Multiple assumptions to calculate emissions.
Emissions from refrigeration	Weighting by fuel factor	Factor combining fuel and motion
Volumes of fruit and vegetables	Mass per product type is distinguished	No distinction between product types (lumped volumes of F&V)
Consumer transport (from shops to CD)	100% of trip emissions attributed to F&V for grocery stores, 7.25% for supermarkets (CHOICE basket used)	Healthy Food Basket used. 30% of trip emissions attributed to F&V for both grocery and supermarket trips.
	Fixed number of trips	Variable number of trips
Scale	Individual trips and ABS CCD's	Aggregated over all supermarkets and grocery store trips

The use of a stochastic model allowed the simulation of 37 variables that included distances and product volumes between supply chain nodes, vehicle factors such as type of vehicle, loading capacity, backhauling, refrigeration and, in the consumer side, the effect of car size and number of trips to major shopping points for F&V. Each of these variables was represented by a stochastic distribution selected to realistically represent the range of values typically observed in Australian food freight movements (described in the full report).

Results

This project did not aim to comprehensively determine greenhouse gas emissions or vulnerabilities, but to investigate the territory, develop methodologies for analysis, provide preliminary indications of significant aspects of supply chain operations for greenhouse gas emissions, and suggest directions for further work.

As the two methodologies were developed and used to elucidate different components of the analysis, they contain a variety of different assumptions and their results are not directly comparable. Considered alongside each other however, some clear themes emerge. The results of the two analyses are discussed below, separately and in relation to each other.

Deterministic Analysis

The results presented below are obtained when the Supply Chain Database Tool is applied on a base scenario i.e. with all assumptions as outlined in Part A of the report and Appendix A.

The analysis undertaken on this base scenario included:

- Summary statistics: estimated greenhouse gas emissions from transport of fruit and vegetables in Victoria; and

- Comparisons between relative emissions (from transport only), as impacted by: origin of produce (NRMs within Victoria, interstate and internationally); seasonal variation; and fresh versus processed F&V.

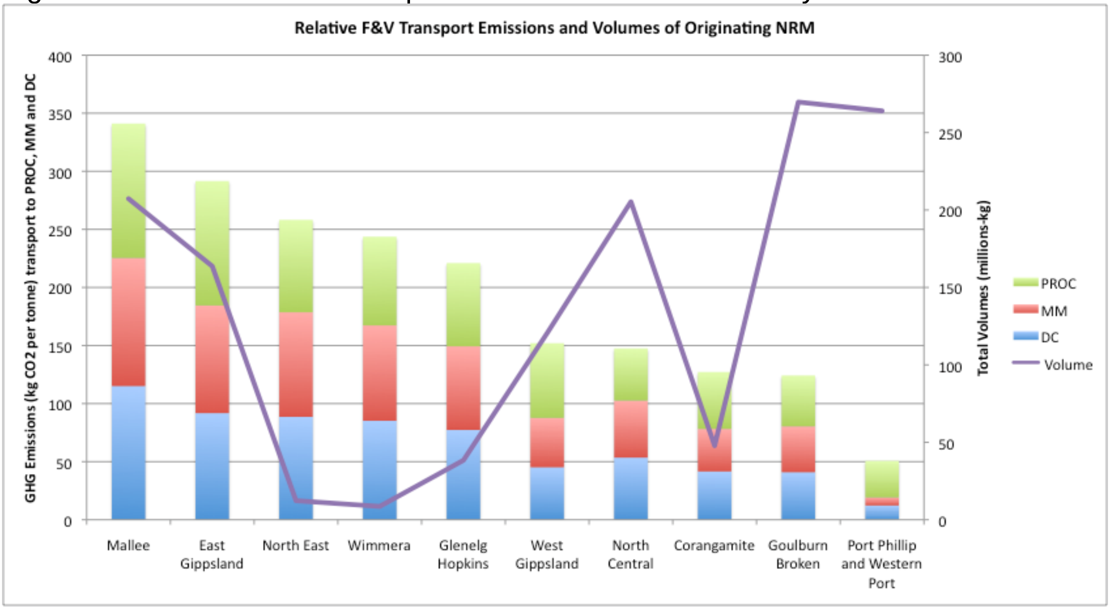
Summary: The overall performance of the supply chain resulted in around 133.8 kg of emissions produced for every tonne of fruit transported, and 134.5 kg of emissions for every tonne of vegetable transported. Overall, the supply chain was estimated to produce 134.3 kg of emissions per tonne of F&V moved.

Processing: The overall transport emissions for processed F&V were estimated at 190 kg CO2-e per tonne, and exceed that for unprocessed F&V (at 128 kg CO2-e) by about 60 kg CO2-e per tonne. This can be attributed to the additional transport legs to and from the processing centres. (NB. It does not account for increase or decrease in refrigeration requirements in transportation of processed F&V).

It should be noted that the extra legs of transport for processed F&V did not overly increase the overall F&V supply chain emissions because the F&V manufacturers based in Victoria (Table 5.1) are located either close to the F&V growing areas or are in Melbourne, near the supermarket DC's. This contribution could become more significant if processors were located at a further distance from growing regions.

Origin of Produce: The significance of distance was evident with the non-even spread of F&V's grown across each Victorian NRM region and the distance from the NRM region to Melbourne. There was a 660% difference in transport GHG emissions per tonne of F&V grown in NRM regions furthest from Melbourne versus the closest (as shown in Figure 1.1).

Figure 1.1: Relative F&V Transport Emissions and Volumes by NRM

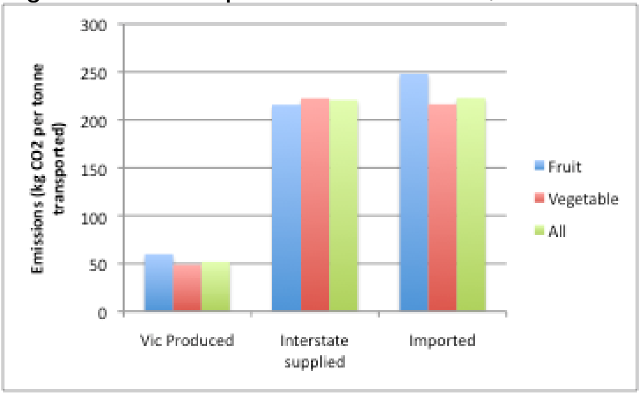


Since production of each fruit or vegetable tended to be concentrated in a subset of NRM regions, the GHG variation between F&V types was also significant with GHG emissions for a tonne of watermelons being 3.5 times that of mushrooms. Different fruits and vegetables had significantly different amounts of emissions per tonne transported, which is largely a factor of the differences in distances from the growing region and the Melbourne Markets or supermarket distribution centres. There is more than a fourfold difference between the items with the highest transport emissions per tonne (grapes, melons, watermelons and oranges) and those with the lowest (celery, beetroots, asian vegtables and parsnips). Transport emissions per $1,000 value (at farm gate) varied slightly, with the lowest transport emissions per $1,000 value coming from mushrooms, Asian vegetables, asparagus and cucumbers.

From the perspective of achieving F&V supply chains with lower transport GHG emissions, the analysis shows that there is a strong case for maintaining the production of F&V in areas closer to the main consumption region of Melbourne. Freight movements that go through processing versus DC's/MM had a much lower impact on GHG emissions compared to the growing region, particularly as the DC's/MM are already located around Melbourne. Unless the agronomic (production) GHG emissions per tonne differ substantially between growing regions, increasing the proportion of F&V grown close to Melbourne is an effective means of decarbonising food supply chains.

Taking a broader geographical view, the difference between Victorian grown and interstate grown products was substantial (see Figure 1.2). The analysis suggests that GHG emissions of transport for F&V grown interstate are four times greater than that of Victorian grown produce.

Figure 1.2: Transport emissions – Vic, Interstate and Imported

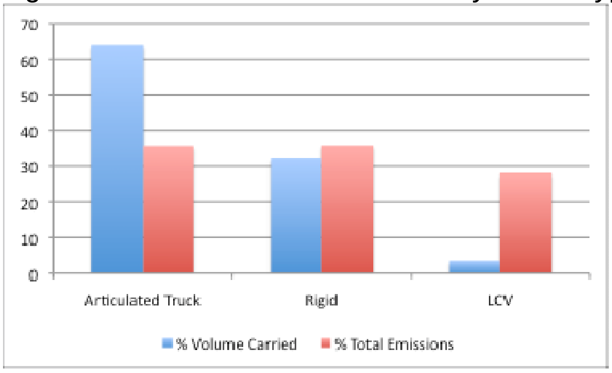


An interesting observation is that the international shipping leg had similar GHG emissions to the interstate road transport leg. However, this does not include ground transport in the foreign country they are imported from, which would likely make them significantly higher.

The deterministic analysis suggests that the household component of emissions is not a significant proportion of the overall emission from the supply chain. This is largely due to the attribution of only 7.25% (as per the CHOICE supermarket basket) of the emissions produced by the trip to the supermarket to fruit and vegetables.

Vehicle types and loads: Figure 1.3 shows the assumed proportion of the volume carried by different sized trucks and the proportion of emissions that this generates. This finding strongly suggests that significant emissions reductions could be achieved by moving to larger trucks. Although only a small percentage of F&V transport is attributed to LCVs (3.5% of total volume), a complete shift away from LCVs to articulated trucks could potentially reduce overall GHG by 26%. Similarly, a complete shift from rigid to articulated trucks could theoretically reduce overall GHG emissions by up to 18%.

Figure 1.3: Volume and Emissions by Truck Type



However, we would expect the improvements to be less than 26% or 18% in practice since LCV's will be more likely used on shorter trips and when it is impractical to use larger trucks. Attempting to move all F&V transport to articulated vehicles would be likely to also have implications for payloads and distances travelled. These results do not take into account congestion aspects, which may worsen (or improve) by these changes.

It is important to note that the relationship of emissions to distance in the base scenario does not allow for a different proportion of different vehicle types for different trip legs e.g. the proportion of articulate, rigid and light commercial vehicles is kept constant over intrastate and interstate trips.

Improved data or closer analysis of this factor would be required to improve understanding of the relationship between emissions and distance. The impact on emissions of changing truck sizes is further explored in Part B: Sensitivity Analysis.

Seasonal Effects: Seasonal variability of production & supply in Victoria had a significant impact on GHG emissions from two perspectives: the total volume varies each month due to total supply variation; and the proportion coming from each NRM region varied significantly due to harvest conditions of each F&V.

The highest emissions per tonne from Victorian produce (for Victorian consumption) are in October for fruits and November for vegetables. The period from June to November result in high emissions because only fruits like mandarins and oranges, which come from NRMs further from Melbourne, are available at this time. The low emission months for fruits belong to February to May, which coincides with the availability of strawberries, pears and apples, particularly from Goulburn-Broken region. Similarly, the period from November to January exhibit the highest emissions per tonne for vegetables because of the transport of high emission items like watermelons, melons, peas and butter beans, particularly from East Gippsland. The seasonal variability may be an underestimate since the harvest season will be shorter than the time window of availability and transport requirements may be variable within a harvest season.

An important observation was that the very low total emissions around October suggests that there is a much greater amount of F&V transported from other states during this period at four times the GHG emissions per tonne. Conversely, the large GHG emissions during March is likely due to supply exceeding demand in Victoria for which a large amount of F&V is transported to other states or internationally during this period. Unfortunately, the unavailability of data on the list and volume of items exported from Victoria (interstate and international) during this period prevents the study from calculating the associated volume of emissions.

NB. If lower Victorian production in October is offset by larger volumes of F&V imported from interstate, the total GHG emissions (local+interstate+imported) in the transport of F&V for the Victorian market would actually be higher in October than in any other month. This would be an important future analysis if supporting data were to become available.

Supply chain vulnerability

Extreme Weather Events: Once established on the base scenario, the SCDT model was used to conduct preliminary testing on two features of potential supply chain vulnerability: extreme weather events and changes to oil price.

The impact of an extreme weather event was simulated by a 25% lost production in each NRM region, to explore whether this had a significant impact on supply chain emissions. The four NRMs with the highest volumes of production have the highest replacement requirements if 25% of production is lost i.e. Goulburn/Broken (76 M-kg), Port Philip/Westernport (70 M-kg), Mallee (58 M-kg) and North Central (54 M-kg). Consequently, these four NRMs produced the biggest impact on emissions from lost production.

The analysis suggested that a 25% loss of production in a NRM region only led to small gains in GHG emissions (mostly less than 4%). However, this finding is an average based on the simulated volume replacements from interstate sources for lost production from one affected NRM at a time, assuming the remaining NRMs are unaffected. Thus the gains in GHG is proportional to the lost volume; the NRMs with lost production volumes of 10 mil-kgs or less had GHG gains of less than 1%, while those with at least 40 mil-kgs of lost production produced gains of 1.5% or more.

Oil Prices: To explore potential implications of increasing oil prices, two scenarios of oil at $2/litre and $2.80/litre were simulated against current farmgate values for fruit and vegetables. These scenarios only accounted for articulated vehicles (the largest and most efficient) and therefore underestimate the actual cost of fuel for F&V transport.

For F&V produced and consumed in Victoria, the scenario of $2.80/litre led to fuel costs reaching 10% of current farmgate value for the most GHG / fuel intensive products e.g. watermelons and oranges (compared to 4% at $1.20/litre). For produce with the lowest GHG / fuel use per $1,000 (primarily those produced closest to Melbourne), the impact of the change in fuel price was much less significant to the overall value (i.e. for apples it changes from 0.5% of value to 1%). These scenarios, which may be conservative,[2] suggest that impact of increases in the cost of oil would be much more signficant for produce being transported from NRMs located further from Melbourne.

From earlier analyses (above), the GHG emissions from interstate transport had been found to be four times that for F&V grown in Victoria (for F&V consumed in Victora). Assuming fuel consumption is proportional to GHG emissions for long distance transport, one would expect fuels costs for each F&V type would be up to 40% of the product value under a fuel cost scenario of $2.8/litre, if transported into Victoria from other states – and vice versa.

Where F&V with a high fuel cost to value ratio are transported between states under the high fuel price scenario, it would be likely to represent a significant increase in the retail price of these items. The actual impacts of this scenario on supply chain viability would depend on who bears the increased fuel costs (retailer, logistics company or producer) and current viability of these chain participants. Furthermore, the proportion of these costs passed onto consumers could have a significant impact on affordability of F&V products. Further vulnerability analysis is required to better understand the implications to each supply chain participant.

It is important to note that this sensitivity to fuel price does not reflect any fuel use except that in transport of the F&V produce i.e. it does not reflect impacts of on-farm fuel use or fertiliser cost.
By Victoria's 'consumption', the demand by processors was included, as the inability to meet demand locally (or reliably) will impact on their costs of sourcing produce (at some oil / carbon price point, there could be a significant impact).

<u>Key Uncertainties</u>

Emissions reduction in food supply chains is a complex analysis as there is a trade-off in costs of change, impact on the local economy, social/health value of the current availability of F&V, and estimated environment implications. While this analysis identified three major drivers (distance from growing region, seasonal variability, transport mode) that appear to provide significant opportunities for reducing GHG emissions, there are significant uncertainties that must be taken into account in considering these results.

Some of the gaps in data, and assumptions made to overcome these, are likely to have led to signficant underestimates of the greenhouse gas emissions in some parts of the supply chain. For example, freight movements at micro level scale could not be identified in this analysis, as data on specific freight movements or companies were not available. This lack of data led to necessary simplifying assumptions, such as:

- Produce is moved directly to DCs using the shortest route, and then directly to stores (ie. there is no movements between DCs) again using the shortest route; and
- Victorian produce is allocated to Victorian consumption first and only sends surplus to other states. This is unlikely to be the case and therefore interstate emissions are probably underestimated.

[2] Even $2.80 could be a moderate fuel price increase – "However, if there is a near-term peak in international oil production resulting in declining future oil supplies, petrol prices could increase to between A$2 and as much as A$8 per litre by 2018." (Future Fuels Forum, 2008)

Other assumptions are likely to have influenced the proportion of emissions allocated to different supply chain legs. For example, the constant allocation of vehicle types regardless of trip distance is likely to have overestimated emissions in long distance trips (i.e. interstate) and potentially underestimated those in shorter trips (where a higher proportion of LCVs may actually be used).

For other assumptions the potential impact is unknown. Some key areas where uncertainties resulting from a lack of data should be considered when interpreting results are summarised on Table 1.2.

1.2 Key Uncertainties in the Deterministic Analysis

Assumption	**Likely Affect on Emissions**
Produce takes most 'efficient' pathway from producer to consumer in terms of distance i.e. moves from production to closest processor, DCs, retailers etc to meet requirement.	Underestimate
F&V sourced for processing direct from production (not via MM) and proportional to production volumes for that region	Underestimate
Assuming that produce moves in the shortest road route in all cases**.**	Underestimate
F&V as a proportion of interstate transport / amount of F&V moved interstate	Unknown
Proportion of vehicle types kept constant in different stages of the supply chain	Unknown
Payloads not differentiated by F&V type i.e. tonne of potatoes requires same transport volume as tonne of lettuce	Unknown
Households would only travel to nearest supermarket and grovery store to purchase F&V	Underestimate
Attributing all consumer trip emissions to F&V for grocery stores, but only 7.25% to supermarkets	Likely bias towards supermarkets

Sensitivity Analysis

The first component of sensitivity analysis was undertaken using the SCDT, to demonstrate how this capability could be used to explore different scenarios (and potential emissions reduction options). As vehicle types had been identified as a key driver of GHG emissions, despite nearly two thirds of F&V volumes already being assumed to travel in GHG efficient articulated diesel trucks, the effect of changing truck use patterns was further explored.

The analysis showed a decrease in emissions by 5.56% for every further 10% increase in the mode of share of articulated trucks from rigid trucks, while keeping the mode share of LCVs constant. The scope for significant GHG reductions through moving towards more efficient existing vehicles will be limited if it is difficult to shift from LCV's to rigid trucks or from rigid trucks to articulated trucks on some routes.

The stochastic model enabled two further, more detailed, sensitivity analyses to be undertaken:

- A complete farm-to-fork analysis (including consumer travel to shops); and
- A farm-to-store analysis that focused on results relevant to the commercial operations in the F&V supply chain.

In this section, the maximum GHG emissions, interpreted as *the maximum contribution potential to GHG emissions derived from the distribution of fresh F&V in Victoria,* was used to compare the relative importance of each link in the supply chains analysed. This maximum contribution is based on the potential values that all variables analysed can take, within realistic supply chain conditions. The main findings of these analyses are summarised below.

The stochastic modelling assumed specific patterns of vehicles used for each supply chain leg. Although there is no data available as to the mix of vehicles used to move F&V loads in commercial supply chains, the following educated assumptions were made:

- From the farm-to-pack house segment, it was assumed that all transport for this segment occurs in non-refrigerated rigid, 2 axle vehicles.
- For the pack house-DCs/MM segment and interstate to DCs/MM, it was assumed that the loads are moved through rigid (2 and 3 axles) and articulated trucks (long haul and B-doubles).
- For the Port of Melbourne-to-DCs/MM segment, a combination of LCVs (light and heavy), 2-axle and 3-axle rigid, semi-trailers and B-doubles was assumed.
- From MM to DCs and MM/DCs-to-stores segments, a combination of LCVs (light and heavy), 2-axle and 3-axle rigid and semi-trailers was asumed. B-doubles are restricted to certain routes and unable to travel through many urban areas. Therefore they mainly go to freight terminals (import, export and interstate focus) but are not used to move large loads between DCs and stores.
- From shops to consumers' households, a range of domestic vehicles need to be considered. This variation was reflected in the emissions factors used to calculate the GHG contribution of the consumer link.

<u>Farm-to-Fork:</u>

- The calculated carbon footprint from farm-to-fork distribution of fresh F&V consumed in Victoria and sold through greengrocers and supermarkets is likely to fall within 82,214 and 318,976 tonnes CO2-e. These results reflect the large data uncertainty –discussed in the deterministic analyses− and the extent to which changes in the variables selected affected the resulting emissions. As the values of variables are refined through more accurate information on commercial distribution of F&V (i.e. the variability is decreased), the resulting GHG emissions would group closer to a mean value.
- In the major supermarket chains (MSC), the distribution segments that have the maximum contribution potential to GHG emissions were (in descending order of importance): transport of F&V from stores to consumers' households, transport from DCs to stores and interstate transport to DCs.
- In the Melbourne Markets (MM) chains, the segments that have the maximum contribution potential to GHG emissions derived from the distribution of fresh F&V in Victoria were (in descending order of importance): transport of F&V from greengrocers to consumers' households, transport from MM to greengrocers and transport from pack houses to MM.

In the farm-to-fork analysis, the most significant factor in transport GHG emissions for fruit and vegetables was found to be consumer travel to purchase them. The signficance of this factor is found to be greater than in the deterministic analysis, which is likely due to:

- a higher proportion of the consumer trip allocated to fresh fruit and vegetables (30% based on a healthy food basket, rather than 7.25% in the average); and
- refined allocations of truck types used in different supply chain legs. In particular, the assumption of LCVs used only for short trips led to a lower estimation of emissions for intertstate segments.

Given the importance of the consumer segment, decreasing the uncertainty of variables that affect consumer travel would lead to more accurate carbon footprints. In particular, the number of consumer trips −which was assumed to be 1.7 weekly per household, but can be as high as 4 trips to supermarkets and greengrocers[3]− would have a significant influence. Other factors include shopping habits and basket share of fresh and processed fruit and vegetables in trips to supermarkets and greengrocers. Similarly, this analysis assumes that all consumer trips to

[3] Freshlogic (2010). *Veginsights: the market-Q4 09. A vegetable market platform analysis plus a profile of the three-month period ending 31 Dec 2009*. Page 27.

supermarkets take place in cars. It does not account for those who shop on foot, cycle or public transport.

It is also important to note that the significance of the consumer trips is largely driven by the households located at distances over 5.5 km, despite the fact that these are a minority (less than 20% of the total Victorian households analysed). If the travel distance (or number of trips) of this minority of households were decreased, this would lead to a substantial decrease in the **total** F&V carbon footprint.

In the context of this analysis, which sought to uncover the most significant causes for GHG emissions in the transportation of fresh F&V, it would be incorrect to disregard the impact of distant households, which is the most significant factor. However, if the analysis was conducted excluding the percentage of households that are located beyond 5.5. km from the nearest supermarket/greengrocer, commercial operations such as interstate transport would be expected to be the most significant factor of GHG emissions. This is reflected in the farm-to-store analysis below. Further discussion on the impact of consumer travels is presented in Appendix E.

Farm-to-Store: While the farm-to-fork analysis presents results that may be of interest to policy makers and urban planners, a second analysis was conducted to pinpoint opportunities to decrease GHG emissions during commercial F&V chains. The following results can be highlighted:

- The calculated carbon footprint from farm-to-store distribution of fresh F&V consumed in Victoria and sold through greengrocers and supermarkets is likely to fall within 44,752 and 124,062 tonnes CO2-e. Again, these results reflect data uncertainty and the degree in which changes in the variables selected affected the resulting emissions. As the values of variables are refined (i.e. the variability is decreased), the resulting GHG emissions would group closer to a mean value.
- For MSC, the segments that had the maximum contribution potential to GHG emissions derived from the distribution of fresh F&V in Victoria were (in descending order of importance): transport from DCs to stores, pack house-to-DCs and interstate transport to DCs. Differences between the GHG emissions of the 2nd and 3rd factors were marginal.
- In the MM chains, the segments that had the maximum contribution potential to GHG emissions derived from the distribution of fresh F&V in Victoria were (in descending order of importance): transport from MM to greengrocers, transport from interstate to MM and transport from pack houses to MM. Again, between the GHG emissions of the 2nd and 3rd factors were marginal.
- Given the importance of the distance between DCs/MM to stores, decreasing the uncertainty of variables that affect this variable would lead to more accurate carbon footprints. Such variables include the specific channels used by greengrocers located in remote locations to source their products, the location of all Victorian greengrocers and the split of volumes from the DCs/MM to stores.

The greater significance of the distance from DCs / MM to stores is likely to result from the multiple trips to stores in distant locations and the low rate of backhauling assumed, compared to the packhouse-to-DC / MM trip. These findings could have implications for location and/or function of outlets and distribution centres, to decrease distances or increase backhauling opportunities.

Conclusions and Recommendations

These analyses, including mapping of current fruit and vegetable movements in Victoria from production to consumer, have improved understanding of the drivers that promote high GHG emissions in F&V transport in Victoria. The report establishes detailed methodologies, analyses, information, assumptions and some baseline numbers that can be used to inform assumptions around transport in lifecycle analyses and other food supply chain projects. These are also aspects that can be improved upon.

When considering how the results of this report can be applied to emissions reduction, it is important to recognise that food distribution systems in Victoria have evolved in response to a wide range of economic, social, technical and political drivers. Reducing fuel use and emissions will be just two of the many factors that need to be taken into account in business and government decision-making relating to food supply chains.

The authors acknowledge that food transport systems designed to achieve the lowest GHG emissions would not necessarily result in the best outcome overall. For example, an optimised transport solution could result in the need of changing current production systems to others with a higher carbon footprint. However, the results of this report suggest that there are significant sources of transport emissions in F&V supply chains in Victoria that can be decreased, through management of both commercial operations and urban planning.

Comparisons of absolute GHG emissions predicted with each model are not possible, due to the differences in system boundaries and the different nature of the modelling approaches. For example, the stochastic approach detected non-linear correlations of GHG emissions with loading capacity of LCVs and distances from stores to consumers, which could not be easily identified through a deterministic approach only. As illustrated in the discussion of the impact of distant households on total emissions, non-linear behaviours can provide valuable information and greatly influence the results of comparisons between both models used.

Overall, key findings of this analysis are:

a) The farm-to-fork transport of of fruit and vegetables in Victoria generate significant greenhouse gas emissions.

b) Distances between the different elements of the supply chain, including consumer markets, have a significant influence on the total GHG emissions generated, as do the type of vehicles used and the proportion of backhauling.

c) Following the rationale of b) and from a transport emissions and fuel use perspective there are significant benefits in retaining F&V production in proximity to the major population centres. In this case, it is Melbourne's consumers.

d) Most importantly, the proximity of retail outlets to consumers (or access without a car) is critical to decrease the consumer transport component in farm-to-fork supply chains.

e) Seasonality has a large influence on the amount of fuel used / emissions generated from the transport of fruits and vegetables. Under current production patterns, Victoria has a large surplus in March and a likely deficit of produce in October.

f) GHG emissions in these analysis act as a proxy for fuel use. Significant GHG emissions also represent vulnerabilities of both supply chain operators and consumers to increases in fuel price.

Methodologies Developed

a) The evaluation of impacts of specific policies and strategies directing the selection of travel modes, vehicle types, and fuel types in transporting FFV will become an increasingly important area of analysis in the study of F&V supply chains.

b) The creation of the SCDT has established an 'infrastructure' for evaluation of such policies through creation of scenarios that are then reflected through combinations of changes to the parameter tables. Improved data availability over time has the potential to increase the capability of this tool to provide 'absolute' emissions accounts of the transport components of food supply chains.

c) Similarly, refinement of the stochastic modelling approach (with improved data sets) could allow for comparative assessments of different options and focus points.

d) Through use of these tools, an improved understanding of how and where GHG emissions occur can help to identify where both incremental and transformational (including whole-of-chain) interventions could contribute. Such interventions may include changes in transport modes and vehicle types, sharing transport infrastructure, reduced sourcing from interstate at certain times of the year, and better linking production regions with consumers.

e) The methodologies could be further developed and applied to investigation of other food supply chains, or more broadly.

<u>Research Extensions</u>

Many of the things that could not be considered within this scope of research could be further investigated in later iterations. With improved data availability and development of more scenarios, the tools would enable more refined analysis. This report has also identified where further priority analyses are needed. We note these analysis and priority data acquisitions required to support them:

a) Due to the severe lack of suitable data on interstate transport, many questions around the seasonal implications of GHG emissions remain unanswered. This includes better understanding the inefficiencies of interstate F&V GHG emissions at a more granular scale such as individual trip movements and companies. A more detailed analysis would help identify more tangible strategies to reduce GHG emissions.

b) The scope of the international analysis needs to be expanded to incorporate airfreight and freight movements between the growing regions in the country of origin to the port of country of origin. This would provide a fairer comparison between local and international supply chains.

c) Supply chains through processors require a more extensive analysis. In particular, data of F&V transported between states for processing is required. Also, GHG emissions of activities within the processor need to be considered to provide a balanced comparison with fresh F&V supply chains.

d) Seasonal variability in the demand of transport vehicles will also have implications on the level of backloading. We suggest additional investigations be carried out to assess the GHG efficiencies of the road transport from the NRM regions, throughout the year. This would need to be assessed in terms of types of vehicles throughout the year, backloading, and implications of peak demand and excess capacity.

e) An important analysis would be inclusion of GHG emissions for F&V consumed in food service outlets, and potential freight inefficiencies explored. This is a very complex set of supply chains and there are several thousand food outlets in Victoria. They vary in terms of small restaurants with local ownership, to large franchises (e.g. MacDonald's, KFC) with large complex supply chains.

f) More data is needed on the proportions of different vehicle types used in different supply chain legs and the variables that affect the consumer trip.

The significance of the last mile in the stochastic analysis suggests that a more in-depth understanding of the 'last mile' effect on food distribution systems would be of interest. In particular, this could consider:

- Are the 'last mile' emissions as significant for other product types as the stochastic analysis suggests they are for fruit and vegetables?
- Given the significant contribution of rural households on the overall carbon footprint generated by consumers' travel to their nearest supermarket shop, what innovative food distribution systems can be more effective in decreasing the 'last mile' to rural households?
- What would be the impact of adding more food outlets to decrease consumers' travel intensity? The commercial realities of mass distribution may inhibit this solution, particularly in

rural areas. However, the transport of food by supermarkets to households, or increase in smaller outlets, could contribute (as discussed in Estrada-Flores and Larsen (2010)).

- If increasing the number of food outlets is an option to decrease the impact of the Victorian 'last mile', how these improvements compare with the increase in upstream distribution operations required to supply the extra stores.

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