Food distribution systems in a climate-challenged future: fruit and vegetables as a case study.

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Introduction and Background

Current disruptive events such as the turmoil of global financial markets, the growing concerns on the relationship between food production and environmental footprints and the effect of increasing production costs on the affordability and security of food can lead to a profound transformation of food production systems (Estrada-Flores, 2008, Archer, 2009).

Under this challenging scenario, how can the global agri-food sector respond to food security and sustainability challenges while remaining a viable proposition for farmers, manufacturers, distributors, retailers and consumers? Answers to this question require a holistic vision, whereby the financial, environmental, social, technical and regulatory performance of food chains is conceptualized as a dynamic and cumulative function of each link's performance.

This holistic approach should be placed in the context of each operation in the food chain. For example, transport is considered to be one of the largest emitters of greenhouse gases (GHG) due to its direct use of fuel and its role in road congestion (Spedding, 2008). The total emissions of food transportation depend on the inbound and outbound logistics providers contracted by farmers, wholesalers and retailers, and ultimately, the consumers that travel in cars or public transport to buy their weekly groceries from stores.

Early attempts to measure the environmental impact of transport focused on the distance travelled by foods ("food miles"), recognising that there is a direct correlation between food travelling large distances and energy use. However, it is now clear that "food miles" cannot be used as a sole indicator of the environmental impact of food chains (Saunders, 2006, Smith, 2005, Rama and Lawrence, 2008). Even in the context of "distance travelled", the common approaches of "food miles" overlook aspects such as:

a) The embodied energy of supply chain infrastructure such as ambient and refrigerated warehouses and transport vehicles, which varies according to the distribution strategy.

b) The different combinations of road vehicles that can be utilized during the lifecycle of the product (e.g. car, small vans, medium and large trucks).
c) The effect of varying degrees of logistics technologies on transport emissions (e.g. diesel-electric hybrid trucks *vs* traditional trucks).
d) The different types of fuel used (e.g. petrol, diesel, ethanol) and its different contribution to global warming.
e) The difference between conventional production *vs* intensive (e.g. glasshouse) production in the distances between farmers and consumers.
f) The effect of different distribution strategies on the distance travelled. For example:
    - The use of fully loaded trucks *vs* partial loads.
    - The impact of empty backhauling *vs* load matching.
    - Differences between cooperative approaches through transport sharing *vs* competitive and non-cooperative approaches.
    - Sharing of transport infrastructure between different farms with different agricultural systems.

Although "food miles" cannot be used as a representative sustainability indicator across all food supply chains, measures such as the reconfiguration of food distribution systems to reduce distances travelled, the application of logistics innovation and the management of supply chain flows can indeed lead to significant reductions in the carbon footprints of foods. Further, broader sustainability and regional / community development benefits can be derived from increasing the contribution of local and regional food chains in a national food distribution system.

A greater understanding of where and how greenhouse gas emissions are generated in Victorian food distribution systems is needed to move this debate beyond the overly simplistic concept of "food miles – good or bad".

Furthermore, while we are responding to the need to dramatically reduce greenhouse gas (GHG) emissions across our economy (and globally), we are also beginning to grapple with the impacts of climate change and the limits to the fossil fuel resources that have underpinned the development of our current food systems. The vulnerability of food distribution systems to these factors can significantly impact food security. Emerging food distribution models can reduce future vulnerability to inevitable and unpredictable stresses and shocks such as extreme weather events (EWE) and both gradual and sudden oil-derived fuel cost increases.

In this context, vulnerability is defined as the existence of random disturbances or disasters that lead to deviations in the normal supply chain of fruit and vegetables (Svensson, 2000). Such deviations can translate into (1) under-supply of products to manufacturers, retailers and ultimately, consumers; (2) product price spikes; and (3) detrimental effects on product quality and safety.

A robust (i.e. resilient) fruit and vegetable supply chain (FVSC) strategy is desired because of its ability to continue to function in the event of disruption in some of its stages (Vlajic et al., 2008). A well designed FVSC can adapt to a dynamic environment.

The Victorian Eco-Innovation Lab (VEIL) at the University of Melbourne recently engaged Food Chain Intelligence and CSIRO to (1) conduct research on best practice food distribution systems that can achieve significant environmental improvements (i.e. reductions in emissions); and (2) assessing the vulnerability of these novel systems at different stages of the chain. This project is also supported by the Department of Innovation, Industry and Regional Development, Sustainability Victoria and the Department of Planning and Community Development.

Fruit and vegetables will be used as a case study. The project aims to deliver on the following areas:

- Identification, description and qualitative analysis of emerging innovations in food distribution across three categories: urban, local and regional chains; government led and self-regulatory approaches; and supermarket-led initiatives.
- The analysis of patterns, motivations and trends in the development of novel food distribution systems.
- Comparison of current and new food distribution systems using indicators that reflect the performance on these systems in two areas: (a) greenhouse gas emissions; and (b) vulnerability/resilience of model in the context of EWE, oil price fluctuations and other events that disrupt distribution systems.
- Overview of barriers and opportunities for application in Victoria.

Victorian fruit and vegetable distribution as a case study

In comparison to other sectors such as livestock and broadacre crops, horticultural production can be regarded as a low emitter of greenhouse gases. A preliminary benchmark of the emissions contributed by vegetables production (O'Halloran et al., 2008) suggests that horticulture adds about 1 Mt CO2-e per year to the Australian carbon footprint. However, this value cannot be used as a horticulture carbon footprint indication because it only includes: (a) field horticulture; and (b) the activities before farm gate. No accurate National or State estimates of the emissions from the entire fruit and vegetables chains (including usage and embodied energy of transport, manufacturing, packaging, cold chain and retailing) is available.

Fruit and vegetables present an interesting case study due to the following aspects:

- Horticultural chains in Australia are mainly focused into the domestic market.
- The supply chain approaches vary from direct farmer-consumer selling (e.g. farmer's markets) to highly complex retail networks with several players (e.g. wholesalers, processors) along the chain.
- The Victorian production of horticultural products is significant; in 2005, horticultural production contributed with 20% of the total value of the State's agricultural production[1].

[1] DPI, 2008.

- The seasonal variability of supply in Victoria and interstate trading is high, due to variable growing conditions across Australia and despite consumer demand for all year round availability of fresh produce.
- In 2007, 27% of the total fruit and vegetable processing industry was established in Victoria.
- The perishability of fresh fruit and vegetables is a limiting factor in the distribution strategies that can be used for these.
- Fruit and vegetables are critical to meeting the requirements for a healthy diet. Fewer than 8% of Victorians currently meet the recommended fruit and vegetable intake – and the cost of fruit and vegetables has increased well above CPI. Affordability and availability of fruit and vegetables is fundamental to food security.
- Current horticultural distribution systems are significantly vulnerable to interruptions in energy supplies used for production, processing, refrigeration, transport, retailing and domestic storage. We believe that there are opportunities to decrease the current levels of vulnerability through the adoption of novel distribution models.

Supply chain disruptions

A potential outcome of climate change in Australia would be an increase in the frequency of EWE. These can damage crops and hamper distribution activities. For example:

- In March 2006 Cyclone Larry ruined 200,000 tonnes of bananas, worth and estimated $300 million. In addition to the crop loss, the impact of Cyclone Larry on the Australian banana industry left thousands of Queenslanders out of work and caused banana prices to increase by more than 400 %. It took over two years to return to normal harvesting patterns.
- The 2009 floods in Tablelands (QLD) made transport of fruit and vegetables unfeasible through the Bruce Highway[2]. Up to $10 million worth of fresh fruit and vegetables in cold rooms and sheds were stored in cut-off coastal areas.
- Damages to field and protected crops were also registered during the 2009 Victorian bushfires[3]. In the Port Phillip region alone, losses attributed to the heatwave and bushfires of January and February 2009 included 50-90% of raspberry, blackberry and blueberry crops, 20-25% of orchard crops (apples and late season apricots) and 60-80% of the strawberry crop that would have been picked during March. Wine grapes were also damaged through direct fire damage and losses from radiant heat, smoke taint and ash.[4]

A second source of concern on the performance of food supply chains is the peak oil concept. This concept states that the production of crude oil—as well as that of most finite

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[2] http://www.cairns.com.au/article/2009/02/10/27835_local-business-news.html
[3] http://www.foodmag.com.au/Article/Natural-disasters-destroy-food-crops/437366.aspx
[4] DPI (2009), *Dry Seasonal Conditions in Rural Victoria*, Report No. 86

resources in a market economy—grows, reaches a maximum (peak), and then gradually declines to zero (Bardi, 2009).

There is an ongoing debate in the popular and scientific literature that relates to the timing of the peak, the scientific and economic basis of the concept and the likely consequences on all human activities (Hall et al., 2008). While divergent opinions about the timing and severity of the peak remain, in 2009 the International Energy Agency conducted a first detailed assessment of more than 800 oil fields in the world, which covered 75% of the global reserves. This assessment revealed that most of the largest oil fields have already peaked and that the rate of decline in oil production is now running at nearly twice the pace as estimated just two years ago.[5]

In the past 30 years, Australia has been able to cover between 80% to 90% of the total oil national demand (Robinson and Powrie, 2004). However, the national oil production is now in decline, after reaching its maximum rate of extraction in 2000 (APPEA, 2008). In 2008, only half of the national demand for oil was met by domestic production (ABARE, 2008). It is expected that by 2020, Australian-extracted oil will cover less than a third of the national demand (APPEA, 2008).

Oil price spikes can occur when there is a temporary shortage of supply (or fear of undersupply) due to disruptions (e.g. cyclones, wars, strikes). Because oil spikes happen rapidly (< 12 months), it provides insufficient time for the supply chain logistics or value chain relationships to adapt to the rapid increase in fuel price. Increased costs have knock on impacts to crop rotations, farmer debt, and farm inputs, which subsequently affect seasonal distribution and quantity/quality of produce reaching retailers.

Farmers are facing escalating costs in oil-derived products (e.g. fuel, oil, grease, fertilisers and chemicals), which in average represent about 36% of the total farm input costs in cropping operations (Department of Agriculture Fisheries and Forestry, 2009). Food distribution will be directly impacted by increasing fuel costs. In all likelihood, the bulk of these costs increases will be pushed back onto farmers and to some extent, to consumers.

Preliminary selection of FVSC strategies

A range of distribution strategies will be identified and a qualitative comparison of advantages and disadvantages of the broad four categories of food distribution models defined above will be performed (existing; regional; logistics; supermarkets). From this review, we will select 10 to 15 models for further investigation in detail. For each selected model we will explain its operations (i.e. how it works) and what makes it innovative.

An overview of the categories and examples of the distribution systems that may be explored are outlined below.

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[5] http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html

Urban, local and regional chains

The local food movement has its roots in the 1960s movement *back to the land*, initiated in the US as a reaction to the growth of global, multinational food companies. Local food systems promote collaborative building of self-reliant food economies, whereby food production, processing, distribution, and consumption is integrated to enhance the economic, environmental and social circumstances of a particular region.

Current challenges in global food systems include food security, power imbalances in food chains, environmental impact of food transport, obesity and other health issues attributed to the strategies of multinational food companies. The disillusion of consumers on current food systems led to the growth of companies that embrace the concept of local food chains. Examples of such companies are:

- The FoodConnect enterprise in Brisbane (http://www.foodconnect.com.au/) that links local growers with local markets directly. Food Connect is a community shared agriculture enterprise that distributes ecologically sustainable, affordable produce by collaborating with local farmers for a financial return. The produce from Food Connect is all sourced from within a 5-hour radius of Brisbane. Green vegetables will have been picked with the shortest time frame being possible between picking and delivery.
- The “Von hier” (from here) private label brand from the German retailer Feneberg (http://www.vonhier.com/). The project is a joint initiative of the retailer, growers/farmers and social organizations from Brandenburg and Berlin. Mostly organic products are sourced within a radius of 100 kilometres from the retailer's headquarters. Approximately 300 organic farmers and 15 producers form part of the "Von hier" -project that guarantees clients that beef, eggs, vegetables and fruit are of local origin. The market share of these regional products in the Feneberg-supermarkets is about 20 %.
- Aussie Farmers Direct [6]. This is a nation-wide Australian company which provides free delivery services of fresh quality products that are 100% Australian owned and produced. Current products offered include milk, bread, eggs, cream, cheese, smallgoods, juice and fresh fruit and vegetables. It will soon encompass meat products.

The penetration of the “food miles” and “local” food movement is illustrated in Figure 1, which was generated with Google Trends. This figure shows world trends in internet searches using the terms *food miles* and *locavores* [7]. While the *food miles* issue gained popularity in 2005, a response from consumers to favour local food chains (as embodied by the *locavore* concept) started to gain momentum in 2007 and the volume of searches

[6] http://www.aussiefarmers.com.au/

[7] A locavore is a consumer who prefers food produced locally or within a certain radius of his/her neighbourhood (50, 100, or 150 km). The locavore movement encourages consumers to buy from farmers’ markets or even to produce their own food, with the argument that fresh, local products are more nutritious and taste better.

is now comparable to the interest in *food miles*.This suggests that consumers are moving from a position of concern to a position of action in this issue.

FIGURE 1. Volume of internet searches using the terms "food miles" (blue line) and 'locavore' (red line). Source: www.google.com/trends. Search performed in 25 Sept 2009.

Government-led and self-regulatory approaches

Examples of this type of model include:

- The ECR Sustainable Distribution Group initiative (UK), which aims to save food and grocery industry mileage by sharing vehicles and improving the efficiency of warehousing networks.
- The SmartWay^{SM} Transport, an innovative collaboration between EPA (USA) and the freight sector designed to improve energy efficiency, reduce greenhouse gas and air pollutant emissions, and improve energy security.
- The Clean Cargo Working Group (USA), which is a multi-sector, business-to-business collaboration between ocean carriers, freight forwarders and shippers of cargo. Members of this group include Coca-Cola, Wal-Mart, Chiquita Brands and Starbuck's, among others. Tools used to enhance communication between participants are annual environmental surveys, intermodal emission calculators and CSR performance surveys.

Supermarket-led initiatives to sustainable distribution

Examples of this type of initiatives include:

- The Woolworth's Environmental Sustainability plan (Australia). Woolworth's aims to achieve a 25% reduction in CO_2-e per carton delivered by 2012 through the reduction of the distance travelled by the product, the introduction of new vehicle designs (*e.g.* hybrid vehicles) and the use of alternative fuels.
- The Woolworths Proprietary Limited initiative (South Africa) aims to reduce relative transport emissions by 20%, through restricting airfreight of food products and sourcing food regionally wherever possible reducing reliance on long distance road transport.
- The Wal-Mart's Sustainability 360 initiative (USA) aims to reduce the number of trucks by re-designing the supply chain network, changing the presentation and size of food products and using auxiliary power units in their truck fleet.
- The redesign of the Tesco distribution network (UK) aims to reduce 50% emissions per case by 2012. Tesco holds over 76,000 SKU's and 95% of volumes delivered via centralised distribution. Its current supply chain infrastructure includes 29 warehouses and over 2,000 vehicles travelling 659 million km across the primary and secondary transport operations. Tesco is measuring the carbon footprint of three of its major food categories (tomatoes, potatoes and orange juice). Tesco has also committed to reduce packaging by 25% over the next 3 years.

Packaging and processing-led initiatives to sustainable distribution

Examples include:

- Re-usable packing crates – CHEP.
- Decrease of volumes to achieve better loading efficiencies in trucks.
- Houston's Farms in Tasmania are farmers and processors of baby leaf fresh cut salad mix. The company has taken initiatives to assess carbon footprint on current practices and develop possible mitigation strategies in processing and supply chain optimisation. The development of a carbon calculation tool for their agri-business is under way to explore packaging efficiencies (e.g. plastic films and technology) in their distribution system (Clark, 2009).

From these models, we will select one in each category for a closer exploration of the motivations and experiences of a key participant, and quantitative analysis and comparison with the status quo.

Approaches for the comparison of food distribution models

The key performance indicators (KPI) used to assess the FVSC strategies must reflect: (a) the GHG emissions produced; (b) the vulnerability of the particular strategy to EWE and oil prices.

To further understand the concept of vulnerability in the context of food distribution systems, the concept of resilience (which can be considered an antonym of vulnerability) is also required. Resilience is often used as the ability of a system to cope with shocks and adapt while still delivering critical functions. This adaptation may be achieved through flexibility and a self-organising ability to better suit new conditions. Therefore, in this study we will analyse the characteristics that make a supply chain strategy “resilient”. Rather than developing quantitative performance indicators for “resilience” we will qualitatively assess the ability of FVSC to “bounce back” following disruptions such as an EWE or an increase in oil prices.

The assessment of FVSC also need to consider aspects such as the shelf-life of fruit and vegetables and the financial cost of transport to supply chain partners, which are both limiting factors to some potential distribution models. For example, as a response to flooding of roads normally used for the transport of perishables, some growers may choose to store their products until the roads are transitable again. This strategy needs to be tempered with the loss of product quality and shelf-life during the non-scheduled delay. If the product quality arrives at the buyer’s premises with an unacceptable level of quality, the uninsured grower will bear the cost of transport, the disposal costs of the rejected fruit and any contractual liabilities that may have been put in place by the buyer. Other growers may choose to transport the produce by airfreight, in which case the transport costs will escalate but the buyer is less likely to reject the load due to quality losses.

Therefore, it is highly likely that tradeoffs between emissions, vulnerability, product quality/safety and financial sustainability will need to be considered when assessing FVSC strategies. These aspects will be included in a high level discussion in the qualitative analysis of the novel distribution models – both as pertaining to the specific FVSC and the function of that supply chain in the broader fruit and vegetable delivery system.

A quantitative analysis of these tradeoffs is likely to require a modelling approach to test different food distribution strategies under the same set of conditions. These conditions will be selected to reflect a range of realistic EWE and oil prices scenarios, which in turn will allow inference of the vulnerability of each strategy to these disruptive factors.

Research and development of supply chain models for perishables, taking into account the angles of environmental impact, vulnerability and product quality/safety, is under way, most notably in The Netherlands (Jacxsens et al., 2009, van der Vorst et al., 2009). The approaches normally encompass the use of discrete-event simulation to model the flow of goods throughout the chain, combined with stochastic models for quality parameters and Monte Carlo simulations to add the risk scenarios. This multidisciplinary approach allows evaluation of the supply chain performance under the uncertainty of disruptions in the network. A potential framework for the construction of supply chain simulations to allow comparisons between different FVSC strategies is illustrated in Figure 2.

Another potential approach is the use an LCA software (e.g. SimaPro or GaBi) combined with Monte Carlo simulation to set the risks scenarios, while simplifying the shelf-life and price constrains as fixed values, and not as dynamic parameters that change according to the FVSC conditions.

Both strategies are being considered in this project.

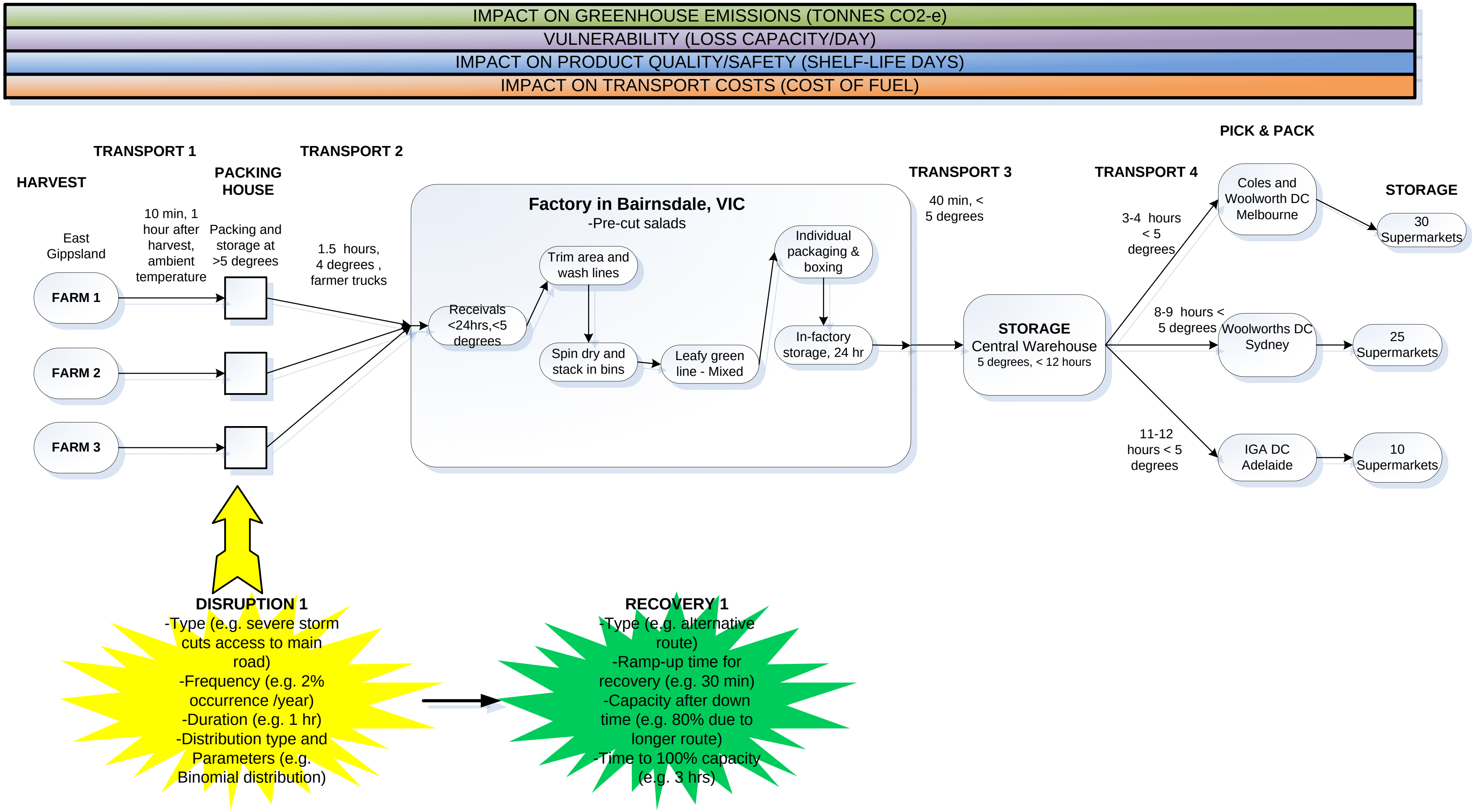

FIGURE 2. An example of the FVSC framework for simulation of alternative strategies, using a fictitious supply chain of vegetable fresh-cuts as affected by severe storms in the production zone. An alternate distribution route allows some recovery of the operation but the recovery of 100% capacity requires 3 hrs to clear the affected roads. The proposed performance indicators for comparisons shown in the boxes at the top are: GHG emissions (e.g. tones CO2-e/day), vulnerability (e.g. loss transport capacity/day), product quality (e.g. loss of shelf-life in days) and financial impact (e.g. fuel costs).

Implications to and from the broader value chain

Assessing the vulnerability of the distribution systems in relation to the broader value chain requires researchers and industry to have a whole-of-chain understanding of the system, which has been a major weakness of efforts published to date (Higgins et al., 2009). Usually, the value chain is assessed in its major components of farming system including harvesting, processing & distribution, and retail/consumer. The vulnerability of food distribution systems, particularly to climate change challenges, is linked to the vulnerability of the crop production and farming system. Rising average temperatures, increased frequency of extreme temperatures, and reduced water supplies will change the areas where different fruit and vegetables and their varieties can be grown (Growcom, 2008, Estrada-Flores, 2009, Deuter, 2008). This will likely disrupt: 1) the convenient proximity of processing, transport and storage infrastructure; 2) the ability to maintain an efficient distribution system in terms of full loads and distances. It may also increase interstate transfers to maintain availability to consumers and create increased imports.

Increased urbanisation, an expanding urban footprint and loss of horticulture land in the peri-urban space (e.g. Sydney and Brisbane) increases the physical length of the supply chain. We expect this would increase the vulnerability of the distribution system to peak oil, oil spikes and extreme weather events.

Future steps

It is expected that the analysis of novel distribution models and their comparison will be finished by March 2010. This project will draw information from a second project (Understanding Victoria's Fruit and Vegetable Freight Movements) led by Dr Andrew Higgins (CSIRO), which will provide a benchmark performance to assess alternative FVSC strategies.

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