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The environmental dimension of food supply chains

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Declaration of interests and affiliations

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I. Introduction

From production through to processing to retail, food supply chains have an often unmeasured impact on the environment. This impact is observed upstream and downstream the chain, as illustrated in Figure 1. Aspects that have environmental impacts include:

- Direct energy use on-farm, during manufacturing and during cooking at the household level.
- Indirect energy use during storage and transportation.
- Greenhouse gas (GHG) emissions associated with fertiliser production; pesticide production and production of packaging.
- Potential toxic effects from the use of chemical agents.

- Use of water for farming and processing, and land use for agricultural production.
- Food and packaging wastage at each stage of the chain.

Increasing regulatory efforts are putting pressure on companies to report environmental performance by July 2008. Simultaneously, businesses offering commercial solutions to assess environmental footprints and recommendations on how to 'green' supply chains have emerged. Companies will need to tread carefully on these matters: the diversity of supply chains and products means that there are no effective 'one fits-all' types of solution in the market. Once software has been used to optimise carbon footprints and consultants have recommended new supply chain strategies, companies must be prepared to implement the planned actions. These steps may involve reorganising supply chain channels, people and activities. In some cases, changes may involve the purchase of more energy-efficient equipment to replace less efficient infrastructure. Therefore, proposed solutions need to be tempered with the level of preparedness of the industry to implement these.

In this submission, I aim to provide a bird's eye view of the environmental issues associated to food supply chains. I make a distinction between operational (performance) related issues, consumer (market) issues and corporate issues, as illustrated in Figure 2. This categorisation could be used as a framework to assess the usefulness of 'greening' solutions and services at different company levels. For example, a particular commercial solution may aid compliance with regulatory reporting. Will this solution also evaluate how 'greening' measures will affect product quality/shelf-life during the chain? Will the solution measure the efficiency of the chain before and after applying environmental improvements? Will it also anticipate consumer's reactions to these changes? Most likely, a combination of approaches will be required to tackle each of the three suggested categories.



Figure 1. Environmental impacts of food supply chains.

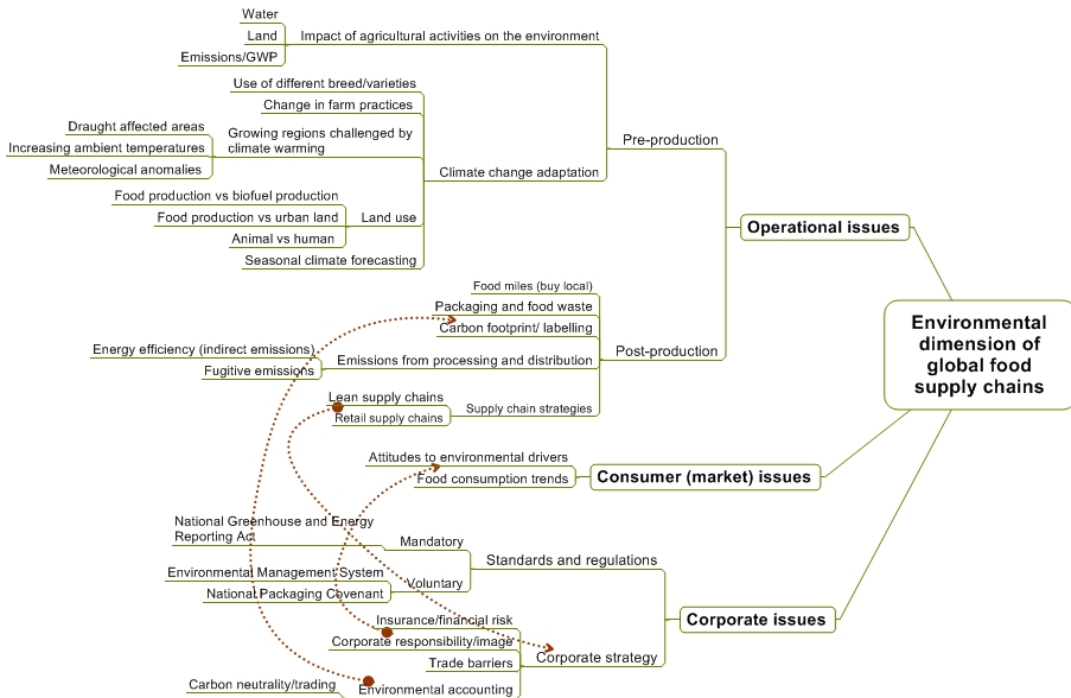


Figure 2. Environmental issues associated with food supply chains.

II. Pre-production performance issues

In the context of this paper, pre-production issues refer to the operations required to grow or farm foodstuff, previous to the actual collection or harvest.

Currently, there are no accurate estimates of the global impact of agriculture on the environment. This gap in information arises from the lack of published environmental data and statistics per country. Extrapolation of published results (mostly related to European food chains) would be inadequate, given the diversity of eating habits, production systems and efficiencies of supply chains around the world. Furthermore, there is no agreed methodology to perform environmental benchmarking.

Although Life Cycle Assessment (LCA) methodologies have been extensively used as a benchmarking tool, LCA has limitations on the assessment of impacts of supply chain operations on biodiversity and water use (1). Furthermore, LCA analyses offer a 'static' view of systems, as opposed to the dynamic nature of supply chains. All LCA impacts are potential, rather than factual. Finally, the accuracy of LCA calculations depends on the quality of available data and the modelling assumptions.

Having said this, LCA remains as the only tool that can provide insights in a variety of industries with a minimum of data and with the greatest confidence. In Table 1, most of the scenarios present LCA estimations of the environmental impact of agricultural activities.

TABLE 1. EXAMPLES OF ENVIRONMENTAL IMPACTS OF PRIMARY PRODUCTION OF FOODS

ACTIVITY	IMPACT		
	WATER	LAND	EMISSIONS/GLOBAL WARMING POTENTIAL (GWP)
Livestock (Australia)	---	58% of the land mass is used for agriculture, mainly for grazing animals and the production of crops used in animal feed.	Livestock emissions were 62.1 Mt CO ₂ -e in 2005, which represents 70.7% of the agriculture sector's emissions and 11.1% of net national emissions (2).
Agriculture (Australia)	---	---	Agriculture contributed 16.8 % of Australia's GHG emissions in 2005, making it the 2 nd largest emitting sector behind stationary energy.
Agriculture (UK)	Agriculture accounted for 18% of the most serious water pollution incidents. Estimated environmental costs due to damage to water quality: £203 million (3).	Estimated environmental costs due to damages to soil quality: £264 million (3).	Entire food chain contributes 18% of total UK GHG emissions – some 116 Mt CO ₂ -e (1). Agriculture alone contributes 40% of the total methane emissions. Estimated environmental costs due to damages to air quality: £760 million (3).
Entire food chain (Sweden)	49% of total eutrophication ¹ sources (4).	13% of total terrestrial toxicity sources (4).	18% of the country's GWP (4)
Agriculture	---	---	Agricultural sources accounted

(US)

for
76% and 30% of total U.S.
nitrous oxide and methane
emissions in 2005, respectively
(5).

Notes:¹ Eutrophication is the increase in chemical nutrients -typically compounds containing nitrogen or phosphorus -in an ecosystem. It may occur on land or in water; ²CO₂-e is the CO₂ equivalents or the amount of CO₂ that would have the same GWP, when measured over a specified timescale (generally, 100 years).

It is also believed that the Australian horticultural sector contributes with significant emissions of nitrous oxide (and perhaps methane) per unit area. However, there are no data sets on emissions from annual or perennial horticulture (6).

There is a symbiotic relationship between food supply chains and climate change: the activities of the former accelerate climate change and the latter will have a drastic impact on food resources in the near future (7). Some of the expected negative effects of climate change on food chains are:

- Increased temperature extremes. It is expected that temperatures will increase in 1 to 6°C by 2070 (8). This in turn will increase our dependence in refrigeration and air-conditioning technologies for food preservation and human comfort.
- Lower rainfall in the world's southwest and southeast, with up to 60% reductions in some areas and some seasons. There are possibilities of more monsoonal rain in the north and reduced soil moisture and river flow. Countries in the lower latitudes are likely to experience the worst effects of climate change, including drought or flooding, or both.
- Countries in Northern Europe and North America may find that initially warmer temperatures and longer growing seasons actually favour agricultural production, but by 2050 the negative impacts of high temperatures and water shortages will be more evident. Negative impacts may include a higher proliferation of insect pests in warmer climates and a greater number of insects' reproductive cycles due to longer growing seasons (9). Other effects could be changing patterns of crop and livestock disease.
- Higher potential evaporation from the soil and accelerated transpiration in the plants themselves, which will cause moisture stress. As a result, there will be a need to develop crop varieties with greater drought tolerance.
- Extreme weather events, including spells of high temperature, heavy storms, or droughts. Disruptions in crop production, transport and distribution systems are likely consequences.
- Sea level increases ranging from 3 to 17cm by 2030. Coasts are projected to be exposed to increasing risks, including coastal erosion.

The Intergovernmental Panel on Climate Change (10) described a number of specific effects for the Australian and New Zealand agriculture. These have been summarised in Table 2. In a recent report (11), ABARE estimated that the global production of wheat, beef, dairy and sugar could decline in 2 to 6% by 2030. In Australia, production of these commodities could decline by 9 - 10% in the same 22-year period. This decline means that Australian agricultural exports would decrease by 11 - 63%. ABARE concluded that "Australia is projected to be one of the most adversely affected regions from future changes in climate in terms of reductions in agricultural production and exports".

TABLE 2. FUTURE VULNERABILITIES OF AGRICULTURAL ACTIVITIES IN AUSTRALIA AND NEW ZEALAND

INDUSTRY	IMPACT
Horticulture –Temperate fruits and nuts (AUS)	Production likely to be negatively affected by warmer conditions because they require winter chill or vernalisation.
Horticulture –Fruit (AUS)	Proliferation the Queensland fruit fly <i>Bactrocera tryoni</i> , a significant threat to southern Australia
Horticulture –Crops reliant on irrigation(AUS)	Production threatened where irrigation water availability is reduced.
Horticulture –apple, orange and pear (AUS)	Growers in endemic Queensland fruit fly areas are likely to have cost increases of 42 to 82%, and 24 to 83% in the current fruit fly-free zone.
Horticulture –Hayward kiwifruit (NZ)	Warmer summer temperatures are likely to increase vegetative growth at the expense of fruit growth and quality. Northern Production of current varieties is likely to become uneconomic by 2050 because of a lack of winter chilling. Kiwifruit budbreak is likely to be delayed, reducing flower numbers and yield in northern zones. Production may depend on the use of dormancy-breaking agents and varieties bred for warmer winter temperatures in the Bay of Plenty.
Horticulture –apples (NZ)	Production likely to flower and reach maturity earlier, with increased fruit size, especially after 2050.
Horticulture – all (NZ)	By 2080, the oriental fruit fly is likely to expand to much of the North Island.
Viticulture (AUS)	Earlier ripening and reductions in grape quality and value are likely by 2030, e.g. price per tonne drops 4 to 10% in the Yarra Valley and 16 to 52% in the Riverina.
Viticulture (NZ)	Increased warming and longer growing seasons may lead to shifting the production of red wine to the south, with higher yields
Wheat (AUS)	Southwestern regions are likely to have significant yield reductions by 2070. North-eastern Australia is likely to have moderate increases in yield. The substantial risk to the industry is likely to be offset by changing planting dates and varieties. Significant increases in nitrogenous fertiliser application or increased use of pasture legume rotations would be needed to maintain protein levels.
All foods (AUS and NZ)	Warmer temperatures and increased rainfall variability are likely to increase the intensity and frequency of food-borne and water-borne diseases. Food security is very likely to remain robust with both countries able to produce more food than they require for internal consumption. Some food imports may be needed temporarily to cover shortages due to extreme events.

The competition for land

Biofuel production is generally seen as a green alternative to diesel. However, conversion of crops that would be otherwise used for animal or human consumption to biofuel can also lead to competition between food and fuel uses. Negative consequences of this competition include an increase in food prices, deforestation, damage to biodiversity, excessive use of fertilisers and pesticides and degradation of land and water (12).

The Garnaut review (13) recognises that a conflict between the use of land for food production, agriculture and forests needs to be addressed by establishing a market mechanism (e.g. a minimum land quota used for food purposes). My view is that policy is also needed to ensure that land use is balanced between food production, urban development and fuel production.

III. Post-production performance issues

Post-production encompasses all activities from primary transformation of foods (e.g. harvest, slaughter, packing house operations) through to manufacturing to retail. Therefore, the issues discussed in this category are related to what we commonly recognise as the “food industry”.

Food manufacturing is likely to be affected beyond the expected shortages of raw materials. For example, by 2020 perishable food chains are expected to depend more in refrigeration, in order to maintain the same quality and safety standards at higher ambient temperatures than those experienced currently. Food safety in particular may become even more important, due to its strong link with product temperatures during storage and transport. Scarcity of water may force manufacturers to change formulations and processes to decrease water consumption. Furthermore, more energy-efficient processes will be required to comply with future carbon targets.

Retail and consumers in 2030 may find that perishable products will have a reduced window of consumption, where shelf-life is likely to become shorter as products are subjected to more risks of temperature abuse. Insurance premiums and shrinkage rates may increase.

The need for more energy-efficient domestic appliances will need to be balanced with the fact that food products will become more expensive and therefore, more valuable. Thus, consumers will demand that domestic refrigerators, freezers and other storage solutions maximise product shelf-life.

The overarching food distribution system will be critical to ensure that food losses are kept to a minimum. Simultaneously, it is likely that the refrigerated transport industry will need to comply with tighter restrictions in the use of diesel. Reduction of diesel for cooling purposes could be achieved by: (a) more efficient insulation (e.g. vacuum panels); (b) refrigeration transport systems powered by cleaner energy alternatives than diesel (e.g. solar panels, electric, CO₂ cycles); (c) increased insulation thickness. The latter may be the push needed to change current Australian road legislation that limits truck’s width to 2.5 m (14), as opposed to the 2.6 m width limit used in Europe, Canada and the US.

However, the issues discussed above are not currently been highlighted in the media. I will discuss below the aspects that are of current concern, identified in Figure 2.

Shortage of raw materials

Some future disruptions expected in the supply of horticultural products were mentioned before. I should highlight that the effects of climate change on milk production are already being felt. In 2006/07, milk production decreased in 5%, due to the severe draught that affected the production areas, particularly the farms across the Murray Darling Basin. As a consequence, 06/07 prices rose from AUS\$2,000 per tonne to AUS\$4,800 per tonne (15).

In regards to crops, the Australian Bureau of Agricultural and Resource Economics (ABARE) expects wheat production in 2008 will double the amount produced in 2007, after rains hit key production areas. However, ABARE has also pointed out that production outlooks are becoming extremely volatile, due to extremely variable weather conditions.

Food Miles (buy local)

Freight transport consumes nearly 25% of all the petroleum worldwide and produces over 10% of the carbon emissions from fossil fuels. Transport is considered to be the largest user of energy in the food chain, due to its direct GHG emissions, but also due to its role in congestion (16). Thus, several British environmental organisations raised the issue of imported foods and their contribution to global warming in the mid-1990s (17).

“Food Miles” is a concept that supports the evaluation of environmental friendliness of foods on the basis of the transportation distances required to bring products to consumers from the farm/grower. The concept ignores the contribution of non-transport activities, such as production. The Food Miles concept has evolved from an European issue to a worldwide issue, where even countries such as Australia, a country whose economy heavily relies in exports, has started to discuss the impact of food imports (18).

Numerous reports have been produced recently, either supporting the introduction of the Food Miles concept as an indicator of sustainable food products (19) or refuting its validity (20) (21). For economies that largely depend in agricultural exports, such as Australia and New Zealand, it will become critical to demonstrate that the Asia-Pacific food supply chains are aligned with good environmental practices. It is unlikely that ‘food miles’ in its present form will be used as a trade barrier (17), but it may become a significant consumer driver for selecting food purchases (22).

Packaging and Food waste

Packaging waste is generated from:

1. The discarded primary packaging or the wrapping or containers handled by the consumer.
2. The discarded secondary packaging or the larger cases or boxes that are used to group quantities of primary packaged goods for distribution and for display in shops.
3. The discarded transit packaging, such as wooden pallets, board and plastic wrapping and containers. These are used to collate the grouped packaged goods into larger loads for transport, which facilitates loading and unloading of goods.

There are different methods to manage packaging waste. These included reuse, recycling (mechanical, chemical and feedstock), composting, thermal treatment and landfill. Some world statistics below show that worldwide, more than 50% of packaging materials are recycled:

- Europe generates about 78.6 million tonnes of packaging waste. About 54% of this waste is recycled (23).
- Packaging represents 10 to 14% of the solid waste going into New Zealand landfills (24). The average recycling rate is 49%.
- In Australia, the total packaging waste in 2005 was about 4.2 million. The recycling rate was 56% (25).

The relationship of packaging waste and food waste is a complex one: packaging plays a key role in avoiding food spoilage and maximising shelf-life and it is therefore pivotal to avoid food waste. In the other hand, food and beverages packaging is the largest contributing category to the total packaging waste.

Food wastage is not particular to developing nations. In fact, a study correlating national estimates of food losses and gross national product per capita showed that there were fewer end use food losses at countries with low levels of income than in high income countries. In the latter category, the estimated losses were 30 to 60% of the total food available for consumption (26).

Food waste is an issue that appears at all levels of the food supply chain and right through to the consumer. In the US, supermarkets, restaurants and convenience stores annually discard \$30 billion worth of spoiled goods (27). In the UK, recent studies indicate that household food waste is 6.7 million tonnes per year, with an estimated retail value of £8 billion (28). A Swedish study (29) found that about 20% of the food delivered to food service institutions is lost. The authors found that the economic value may demand arable land equivalent to 1.5% of the area under cultivation in Sweden. In Australia, the amount of food waste is about 3.3 million tonnes with an estimated value of \$5.3 billion (30).

As mentioned before, food waste avoidance is correlated with the use of preserving technologies (e.g. cooling, freezing, drying, canning), which in turn contribute to global warming through the use of energy and direct emissions. The only way to avoid food preservation is the consumption of foods as soon as these are farmed or harvested. This option is currently unachievable in a global scale for many reasons, including crops seasonality, food trade balances and mismatches between food needs and available resources per country, among others. Even with the application of basic preservation technologies, it is estimated that about 300 million tonnes of produce are wasted annually due to deficient refrigeration worldwide (31).

Although food processing is a necessity, low energy efficiencies in food processing and distribution are not. The food industry has substantial potential for energy efficiency improvements. The re-design of logistics networks can also help reducing the carbon footprint of transport operations. These options are discussed later on this article.

Carbon footprint and labelling

There are several interpretations of what is a carbon footprint. In this paper, a carbon footprint is “the total amount of CO₂ and other greenhouse gases, emitted over the full life cycle of a process or product. It is expressed as grams of CO₂ equivalent per kilowatt hour of generation (gCO₂-eq/kWh), which accounts for the different global warming effects of other greenhouse gases” (32). Carbon labelling is simply the expression of a product’s carbon footprint in the form of a label. A carbon label (or eco-label) may have information such as grams of CO₂ –e, plus declarations of other GHG produced during the life cycle of the product.

Carbon footprinting requires the use of LCA methodology that assesses the inputs (e.g. materials and energetic resources) and outputs (i.e. methane, nitrous oxide, kg CO₂ –e), from the point of production of raw materials to the disposal of the product/service. Therefore, carbon footprinting is closely linked to the knowledge and mapping of supply chains. The Carbon Trust, a private company set up by the UK government in 2001 to accelerate the move to a low carbon economy (33), advocates the use of a common carbon footprint methodology consistent in the following steps:

1. Analysis of internal product data (e.g. formulation, packaging, manufacturing process, storage conditions).
2. Development of a product supply chain process map similar to Figure 1. The individual supply chains of the raw materials used to manufacture the product also form part of the analysis. For example, the manufacture of bread requires wheat flour; although flour is an input to the bread supply chain, flour is also a finished product that has been manufactured from wheat grains. The Carbon Trust proposes that the boundaries are defined by tracing the supply chain back until primary raw materials with zero associated GHG in the final product are identified.
3. Definition of boundary conditions and identification of data requirements. This is an extension of step 2, where a final selection of operations is made. For example, the domestic transport of purchased products from the shop to the consumer’s house is not accounted for, as it would be difficult to determine the specific shopping basket per consumer and the attribution of GHG per product.

Data collection is based on the mass balance of the process diagrams developed in the previous step. Each mass flow stream is associated with direct emissions (e.g. refrigerant leakage, chemical reactions, methane production) or indirect emissions (e.g. electricity, diesel, bio diesel, gas).

4. Collection of primary and secondary data. Ideally, primary (actual) data should be collected. Top down energy consumption data at a plant level is preferred. However, bottom up estimates where individual machinery is monitored for a period of time and the results extrapolated to the energy requirements of a product unit are also useful. To avoid effects such as seasonality and variable production capacities during the year, the analysis of the data collected needs to follow specific methodologies designed for each process. For example, reference (34), provides top down and bottom up approaches to evaluate electricity requirements in industrial refrigeration systems. Similar references exist for other food processes.

When it is not possible to measure the actual direct and indirect emissions of processes, secondary data from databases or other sources can be used. Examples of databases that contain food manufacturing processes are the LCA Food Database (35) and the Australian LCA inventory database (36).

5. Calculation of GHG emissions for the entire supply chain map. This basically consists on solving the mass balances and calculating the direct and indirect GHG emissions. First, the balances are resolved per supply chain step and later for the whole chain.

In step 4, the exclusive use of secondary data should be avoided, as data drawn from the databases represent an industry average. Secondary data and LCA modelling may have low resolution to distinguish specific business strategies with an effect on their carbon footprint. For example, companies A and B manufacture exactly the same products. But company A produces more units per year than company B. An LCA methodology is likely to determine that company A has a higher carbon footprint than company B, based on production rates. But perhaps company A has better incentives for workers or better management. In this example, the LCA approach needs to be complemented with field observations and insights on the companies involved, so specific actions or processes that are helping company A can be identified.

The carbon footprint methodology should be closely aligned with the company's environmental accounting system. Furthermore, the carbon footprint may vary from year to year, depending on the circumstances of the company and the changes affecting production. Therefore, carbon footprinting is a dynamic activity that needs to be performed whenever there are significant manufacturing changes that are expected to decrease (or increase) the environmental impact of the product.

Emissions from processing and distribution.

Emissions from food processing and distribution arise from two sources:

- (a) Direct emissions resulting from releases of GHG to the atmosphere (e.g. refrigerant leakage, emissions from diesel engines).
- (b) Indirect emissions resulting from the consumption of energy (e.g. electricity, gas, LPG, diesel).

Typical energy-intensive operations performed to process foods are:

- A. Heat transfer processes. Typical examples are cooling (e.g. chilling, freezing, cold storage) and heating (e.g. sterilisation, pasteurisation, steaming, cooking).
- B. Mass transfer processes. Typical examples include mixing, centrifugation, grading or moving items through conveyor belts.
- C. Combined heat and mass transfer processes. Typical examples include evaporation, drying, and distillation.
- D. Air-conditioning at retail and at convenience shops.

Refrigerated transport occurs at every step of the supply chain, connecting production centres, warehouses, export destinations, retail outlets and consumer's homes. Refrigerated transport in Australia uses diesel as the main source of energy for both motion and refrigeration purposes. The

energy consumption of refrigerated transport is significant: it is estimated that in 2000, road food transport in Australia was responsible for 5.2 megatonnes of CO₂-e (37), excluding the use of diesel for refrigeration purposes.

The UNEP Working Group for Cleaner Production in Food, based in the University of Queensland, have carried out substantial work in assessing the opportunities for energy efficiency in the Australian food industry. Specific information for various industries can be found in their website (38).

Refrigeration-related processes (e.g. cooling, freezing, air-conditioning, cold storage) are undoubtedly a large contributor to carbon emissions in food-related industries. It is estimated that refrigeration consumes about 15% of all electricity consumed worldwide (put coulomb ref). Estrada-Flores and Platt (39) investigated the electricity usage in the Australian cold chain. Their estimations suggest that the total energy spent to keep an unbroken cold chain from farm to consumer is about 19,292 GWh/year. To add some context to this number, this amount is the equivalent of taking approximately 5.8 million cars off the road each year (or 40% of the total number of cars registered in Australia in 2006).

Some trends in electricity consumption are presented below.

Meat industry

Australia has an annual production of just over 2 million tonnes of beef and 380,000 tonnes of lamb. About 65% and 45% of the production are exported, respectively. Meat products are one of the major contributing categories to the Australian food value chain, representing 38% and 23% of the total value of primary production and processed food, respectively.

Refrigeration uses the largest amounts of electricity in the meat industry, accounting for 40 to 50% of the total use. It is estimated that, in a typical meat plant, refrigeration uses 22,222 kWh/day (40).

Dairy industry

Dairy is Australia's third largest rural industry, with a farmgate value of \$3.2 billion during 2006/07. It is also the largest value-added food industry, with ex-factory sales valued at almost \$9.2 billion each year. The major products are drinking milk, cheese, butter and milk powders. About half of Australia's milk production is consumed on the domestic market, and half is exported. Dairy products generate \$4.2 billion annually in supermarket sales (41).

The energy use of dairy factories depends on the types of products manufactured. For example, the production of market milk uses energy for heating and pasteurisation, cooling and refrigeration, lighting, air-conditioning, pumping, and operating processing and auxiliary equipment. Factories producing concentrated milk products, cheese, whey or powders require additional energy for churning, pressing, separation, concentration, evaporation and drying. Table 1 shows typical percentages of electricity supplied per product.

TABLE 3. ELECTRICITY USE IN THE DAIRY INDUSTRY

Products	Electricity (%)
Milk only	66
Cheese and whey products	27
Mainly powders	21

Source: P. Prasad, R. Pagan, M. Kauter and N. Price. 2004. *Eco-efficiency for the dairy processing industry. Dairy Australia. P.44.*

Fruit and vegetable industry

Australia produces over 6,000 kilotonnes (kt) of fresh fruit and vegetables per year, with a value of \$5.8 billion at farmgate. The production of grapes is the largest of all horticultural products, due to the use of these in the wine industry. The vegetable sector is the largest part of the horticultural industry (40).

The fruit storage sector presents an outstanding opportunity for energy efficiency. Refrigeration systems account for most energy use at these facilities, and potential for savings can range from 10% to over 50% (40). At facilities with no packing line, refrigeration can use 90% to 95% or more of total utility energy use. With a packing line, refrigeration energy use can range from 70% to 80% of total facility energy, with the balance required by packing lines and lighting.

Seafood industry

Seafood represents about \$1.9 billion of the total food primary production (see Fig.2). In recent years, Australian production has fallen due to over fishing, tighter fisheries management, higher fuel prices and ageing fleets, amongst other factors. No published data was available in regards to Australian consumption of energy in seafood-related industries. However, Norwegian studies (42) estimate that frozen storage has an energy requirement of 300 to 500 kJ per storage cubic meter per day. Chilling of fish is normally achieved by the addition of ice and a total energy consumption of 80 to 100 kJ/kg fish. A published survey (43) of a seafood processing plant in Auckland (New Zealand) reveals that a cold storage facility with a capacity of 1,000 tonnes expends about 1.1 GWh per year. This represents about 92% of the total electricity used in the plant. This energy usage is probably comparable to Australian energy figures. A Canadian survey estimated a lower percentage of electricity use for refrigeration purposes (65% to 85%) (44).

Supply chain strategies

It is widely recognised that supply chains are formed by alliances of two or more players (e.g. growers, manufacturers, logistics providers and retailers) to deliver products. However, each company has its own supply chain strategy. It is worth considering the effect of individual strategies on the overall carbon footprint of a product.

For example, we have the perception that lean supply chains should be 'green' by definition. But, is that so?

Although it is reasonable to expect that lean processes (which aim to eliminate wasteful activities) should align by definition with a lower carbon footprint, Venkat and Wakeland (45) found that this is not necessarily true. The authors investigated the relationship between lean supply chain strategies and their effect on carbon emissions. Lean supply chains typically have lower emissions due to reduced inventory levels. However, they also require frequent replenishment at every point in the supply chain. If a lean supply chain is located entirely within a small region, then it would have low levels of inventory and short shipping distances. As distances increase along the supply chain, lean chains may be in conflict with low carbon footprints, thus leading to tradeoffs as well as additional opportunities for optimization. This issue needs to be further explored in the case of Australia, where long transport distances are the rule rather than the exception.

In their search for cost-reduction, supermarkets are always looking for opportunities to make their transport networks more efficient, by moving goods in larger quantities and optimising their delivery schedules. This had led to a decrease in distribution centres around the country, which is what good supply chain practices dictate to decrease inventory costs. However, as mentioned above, this strategy also needs to be considered in the light of carbon footprints.

Supply chain strategies also include the use of refrigerated warehouses and transport for the distribution of perishable foods. Michael Luscombe (CEO, Woolworths Limited), admitted that “Woolworths is the largest operator of refrigeration in Australia –both in stores and in our supply chain” (46), consuming about 3.2 million CO₂ –e in refrigeration and air conditioning. This represents about 8% of the total GHG emissions from the Australian refrigeration and air conditioning sector (47).

Mr Luscombe is targeting a 40% reduction in Woolworth’s energy consumption, through a range of innovations that include the use of co-generation, the installation of cascade systems using carbon dioxide as refrigerant and other measures. Although no comments have been made in regards to carbon reductions in refrigerated transport, this sector has an untapped potential to further decrease supermarket carbon footprints.

IV. Consumer (market) issues

The category “consumer issues” encompasses those activities beyond retail and through to the consumer’s households.

Consumer attitudes to environmental drivers

The interpretation of market research in regards to consumer attitudes towards environmental drivers needs to take into account what David McKinna identified as “schizophrenic consumerism” (48). Dr McKinna stated that the major choice drivers for consumers are taste, value for money, convenience and nutritional benefits. But during market research surveys, consumers tend to overstate the importance of nutrition and price (i.e. “good” attributes), and understate the importance of taste and enjoyment (i.e. “superficial” attributes).

“Schizophrenic consumerism” in market research may erroneously lead to an over prediction of the importance of environmental drivers in the consumer’s food purchase choices. The contradictory information circulating in publicly available reports seems to support this. For example, a publicly

available source reports that in the US, at least 50% of consumers consider one or more sustainability features when purchasing packaged goods (49); in the UK, a second report states that 54% of consumers are influenced by environmental concerns when purchasing foods and drinks (50). However, ACNielsen has reported that consumers are unlikely to be influenced by the environmental friendliness of grocery shops. Other factors, such as good value for money, are more influential in selecting the choice of a store (51).

Food supply chain players may not be able to pass the costs of an improved environmental footprint to the consumers. However, improving the environmental efficiency of the food industry is an alternative to offset escalating energy and waste disposal prices. Those industries that have made an effort to decrease their environmental footprint before 2010 will be more likely to benefit from the emission trading scheme, proposed by the Australian government to cut carbon emissions.

Food consumption trends

Research on the relationship between the emission of GHG and food consumption trends has provided evidence on the higher environmental impact of protein-based diets (e.g. meat, dairy) over diets high in pulses and root crops (52). However, the greenhouse potential of a meal depends in other variables such as degree of processing, choice of processing, preparation technology and transportation distance (53). There is disagreement about which of these factors weights more in the environmental footprint of diets. Furthermore, food consumption patterns vary widely due to geographical limitations, cultural differences, the choice of ingredients and gender differences.

V. Corporate issues

Corporate strategies are strongly linked to both operational and consumer issues. As any manager in private or public practice knows, there are corporate forces that may make or break initiatives that may seem logical or even mandatory. Environmental initiatives are not the exception.

Corporate strategy

Recently McKinsey surveyed 2,192 executives around the world about their views and attitudes to global warming (54). The survey found that 60% of global executives view climate change as important to consider within their companies' overall strategy. Further, nearly 70% see it as an important consideration for managing corporate reputation and brands, and over half say it's important to account for climate change in areas such as product development, investment planning, and purchasing and supply management. In the regulatory arena, 82% of executives expect some form of climate change regulation in their companies' home country within five years.

Although we would expect that these views would translate into action, the same survey found that climate change is considered only occasionally when managing corporate reputation and brands, developing new products, or even managing environmental issues. Furthermore, 36% of executives say their companies seldom or never consider climate change when developing overall strategy.

In the case of food supply chains, the gap between executive opinion and implementation can be partly attributed to the diversity of the industry. Although the food industry would benefit from a united, strategic approach to the issue of climate change, group interests in the supply chain are not

always aligned. The creation of an overseeing public body that helps the industry in designing a value chain-based strategy, incorporating innovation as a key factor for survival, could help.

At a business level, climate change and adaptation measures are seen as another cost to the company. However, some companies encourage environmental initiatives because there is a good business case behind. Benefits could include saving money through energy efficiency and waste minimization, marketing low-carbon products, or entering early into the future carbon offset markets.

The Australian Industry Group (55) proposes ten steps to bring climate change into the corporate agenda. These are:

1. Obtain board and senior management understanding and commitment.
2. Establish a baseline for sustainability performance.
3. Establish sustainability measurement and reporting systems.
4. Establish sustainability objectives and integrate these into corporate strategy.
5. Take leadership on big issues (i.e. relevant key topics).
6. Initiate whole-of-company engagement incorporating sustainability objectives into individual KPIs.
7. Establish multi-disciplinary teams ensuring all areas of the business are engaged.
8. Engage with stakeholders and develop partnerships, including internal and external stakeholders, suppliers, customers and financiers.
9. Foster a culture of innovation and institute appropriate rewards.
10. Build skills capacity of all employees.

Having investigated other sustainability strategies (56), I would like to add the following to this list:

11. Build a business case for environmental initiatives.
12. Change the vision of sustainability from a project-based issue to a core value issue.
13. Share the progress and communicate environmental activities and outcomes widely.
14. Having the stakeholders' expectations in mind, take the steps required to ensure the survival and success of the company in a climate-challenged future.

In this section, I would like to discuss the following issues:

- The current corporate obligations, in the context of recent developments on regulating national emissions.
- The implications of these developments on the financial position of the company and the need to integrate these developments into strategic planning.

Standards and regulations

In Australia there are several environmental monitoring and reporting initiatives, both mandatory and voluntary. A non-exhaustive list includes the National Greenhouse Gas Inventory (NGGI), the National Pollutant Inventory, the Greenhouse Challenge Plus, the Greenhouse Friendly programme, NSW & ACT Greenhouse Gas Abatement Scheme, the South Australian Greenhouse Strategy and the Victorian State Environment Protection Policy (Air Quality Management), among others.

In regards to voluntary programmes, an important environmental agreement is the Greenhouse Challenge Plus Program (57). This is a cooperative partnership between government and industry to improve energy efficiency, reduce greenhouse gas emissions, and integrate greenhouse issues into business decision-making. Membership into this programme ensures access to fuel tax credits of more than \$3 million in a financial year.

The regulatory National Pollutant Inventory (NPI) is an internet database that concentrates data from the Federal Government, States and Territories. All individuals can access the database, which provides information on the concentration of certain substances that are emitted in Australia to the environment via air, land and water. Only companies that exceed certain threshold levels of the chemicals on the NPI list are required to provide information (58).

Another self-regulatory measure that is relevant to the food industry is the National Packaging Covenant (NPC), developed between the industry and the Australian Government (59). The Covenant is designed to minimise the environmental impacts arising from the disposal of used packaging, conserve resources through better design and production processes and facilitate the re-use and recycling of used packaging materials. Therefore, food manufacturers, retailers, packaging manufacturers and fast food companies are involved in this initiative. The NPC requires that its membership submit documents, action plans and annual reports that demonstrate their aims and achievements against Covenant goals and targets. The 632 Covenant Signatories have very specific plans, with targets developed by each company, using the specific environmental performance goals and indicators designed by NPC.

The most recent legislative effort to establish a single, national reporting system is the National Greenhouse and Energy Reporting Act (NGER). The Act requires corporate reporting of greenhouse gas emissions, abatement actions, and energy consumption and production, starting from 1 July 2008. The corporations that need to comply from this date are:

- (a) those that control facilities that emit 25 kt or more of CO₂-e, or that produce/consume 100 terajoules (TJ) or more of energy; or,
- (b) their corporate group emits 125 kt or more of CO₂-e, or produces/consumes 500 TJ or more of energy.

Lower thresholds for corporate groups will be phased in by 2010-11.

To place context on the initial thresholds that require compliance by July 2008, I refer again to the Woolworth's case, where the corporate group produces about 4,000 kt of GHG, with 80% of those emissions associated with refrigeration and air conditioning systems (46). Other equally large supermarkets are also likely to be above the initial threshold, as well, as large food manufacturers. For example, in 2005 Murray Goldburn was consuming more than 1,080 TJ of electricity annually, across 8 manufacturing and other sites throughout rural Victoria, including their logistics complex in North Laverton (60). Other example is AMCOR's bottling business, which spent about 108 TJ in 2005 (60).

It is worth pointing out that a corporation that controls two or more facilities may need to comply with the mandatory reporting for those sites that fulfil threshold (a). However, the corporation would only need to report the entire corporation's emissions if the cumulative expenditure of their

facilities fulfil threshold (b). Likewise, a corporation may have facilities that, individually, do not fulfil threshold (a). But if the site's cumulative impact fulfils threshold (b), the corporation will still have to report the entire corporation's environmental impact.

To aid NGER compliance, companies could implement environmental management systems (EMS), which provide a managerial framework for continuous improvement and benchmarking of a company's environmental performance. The establishment of an accredited EMS normally precedes full ISO 14001 certification. The benefits of an ISO 14001 accreditation are: (a) ISO accredited companies are seen to be more proactive than others that wait for mandatory regulations; (b) ISO methodologies allow a systematic assessment of environmental activities in the company; (c) the framework is "management-friendly", thus management feels that they can highlight improvements in their area and cost savings due to reduction of waste, energy and others; and (d) ISO paper trail allows its use as a tool to handle legal liabilities and demonstrating due diligence.

Insurance/financial risk

The insurance industry is one of the world's largest industries, collecting US\$4.3 trillion in annual premiums worldwide in 2005. In fact, only two countries (U.S. and Japan, with GDPs of \$12.5 trillion and \$4.5 trillion respectively), have GDPs that are in excess of worldwide insurance premiums (61). Predictably, the insurance sector is exposed to significant financial losses with global warming, where extreme weather conditions (e.g. floods, hurricanes, severe thunderstorms) will increase catastrophic risks to properties and individuals. For example, weather-related insurance claims in 2005 represented about 2.1% of the global value of annual premiums. Nearly US\$60 billion were triggered by hurricane Katrina, alone (62).

In response to the Katrina event, many insurers moved out of the US coasts. Other risk management measures implemented by insurers include decreased insurance coverage through increased deductibles, reduced limits, and new exclusions.

However, some insurers have moved into a proactive approach, capturing the emerging opportunities arising from alternative energy sources. An example is the AIG Global Alternative Energy Practice, which will insure US-based clients engaged in biofuel, hydroelectric, geothermal, solar and wind operations (63). In Australia, IAG has developed the Climate Help website, which is an online tool that enables users to offset their carbon emission by buying carbon credits. Dr Evan Mills, from the IPCC working group, suggests more innovative insurance products (64), such as:

- Energy savings insurance: protects the installer or owner of an energy efficiency project from under-achievement of predicted energy savings.
- Reduction of insurance premiums to adopters of 'green' technologies or those companies that prove a low risk profile, through carbon emission disclosure.
- "Green-buildings" insurance: covering disruption of energy services, where energy is supplied by solar or other alternative sources. Green upgrades are also an attractive insurance market.
- Directors and officers liabilities due to underperformance in carbon management.

- R&D funding: the insurance sector has had a limited role in funding R&D to seek for an overall reduction of the impacts of climate change. However, in the US there has been some collaborative research between public R&D organisations and insurance firms.
- Offering Carbon Risk-Management and Carbon-Reduction Services. These services may include risk management of companies investing in emissions trading markets.

Carbon trading/offsetting

Emissions (or carbon) trading schemes allow the Government to regulate the amount of emissions produced in aggregate, by setting an overall cap. The carbon trading scheme allows companies to determine how and where the emissions reductions will be achieved.

Participating companies are allocated a number of carbon credits or allowances, each one of these being equivalent to one metric tonne of CO₂-e emissions. Companies that emit in excess of their credit allocation will need to purchase further credits from the market. Similarly, a company that emits less than its credit allocation can sell its surplus allowances. Therefore, emissions trading gives companies the flexibility to meet emission reduction targets by: (a) reducing emissions on site or (b) by buying allowances from other companies who have excess credits. The overall environmental outcome is not affected because the amount of credits allocated is fixed.

Under an emission trading scheme, the impact of carbon emissions becomes clearly linked to the internal cost of doing business and therefore visible in the profit & loss and the balance sheets of a company.

VI. Innovation strategies to reduce the environmental footprint of food supply chains

It is clear that food supply chains will face tough conditions that can only be challenged successfully through increased accountability, transparency and innovation. We have discussed the first two aspects in the previous sections. This section will discuss aspects of environmental innovation.

In Europe, Forward Commitment Procurement has been highlighted as a model capable of accelerating the commercialisation of environmental innovation. Forward commitment procurement (FCP) is defined as “a commitment to purchase, at a point in the future, a product or service that does not yet exist commercially, against a specification that current products do not meet, at a sufficient scale to enable the investment needed to tool up and manufacture products that meet the cost and performance targets in a specification” (65).

In an FCP model, a public sector organisation commits to purchase a pre-defined quantity of a product\ technology, currently under development but not yet available as a commercial offering. The commitment is for a future date and is based on a specified product performance being achieved. When the product has been developed meeting this performance specification within the agreed timeframes and framework, the organisation purchases the product at a specified volume and cost, at levels that encourage supplier investment to ensure economies-of-scale. The private sector would react by freeing investment to search for innovations that respond to those specifications. Once the product/service has entered the market, normal market conditions will determine competition and price (66).

Although in the FCP framework a government department acts as an early adopter, there is a growing interest of private investors in the environmental innovation market. Globally, the development of 'green' technologies attracted an estimated US\$3 billion venture capital last year. Eighty four percent of the capital originated from the US (67). The areas that have attracted more attention from investors are solar energy, transportation and biofuels. Potentially, insurance companies could contribute to offset R&D costs. We have already discussed innovative possibilities in which the insurance sector could encourage environmental innovations.

Some specific innovative technologies and practices that have been discussed recently are:

- Use of food waste to produce biogas. Rotting food releases methane, a more potent greenhouse gas than CO₂. Methane can be used to produce biogas. Biogas-fueled cars can reduce CO₂ emissions by anything from 75% to 200% compared to cars powered by fossil fuels (68).
- In primary production, more efficient production methods that give a higher yield would lead to a better utilisation of fodder and less soil tillage.
- In packaging technologies, the development of biodegradable films and boxes has also been investigated. Some examples include the use of corn-derived polylactic acid and edible milk protein skins, among others (69).
- The reduction of fuel consumption of transport systems (specifically ships and road transport) is also a subject of research. In Australia, a company has developed a two-cycle orbital combustion process (OCP) engine, which is 50% lighter, takes up 70% less space, and consumes 30% less fuel than a four stroke engine. The power source is suitable for motorcars, inboard and outboard marine engines (70).
- The use of multimodal transportation in Europe has been highlighted as an immediate measure to decrease the emissions of food transportation. For example, road transport of produce from Italy to Stockholm produces twice the emissions than transportation by rail. To facilitate rail transportation, containers that can be easily transferred from one mode of transport to another can be used (71).
- Rethinking our diets is not out of the question. A Swedish study in 2003 suggested that organic beef, raised on grass rather than concentrated feed, emits 40% less GHG and consumes 85% less energy (52).

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