Greening Food and Beverage Value Chains: the Case of the Meat Processing Industry

A report for the UNIDO Green Industry Initiative

UNIDO
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Green Industry

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EXECUTIVE SUMMARY

The demand for meat and meat products is on the rise globally, particularly in Asia. Since 1961, per capita meat consumption in the region has grown by a factor of 15; in China alone it has risen by 130% since 1990 (FAO 2012). The increase in demand is driving the intensification of meat production systems whilst global supply chains are being developed. Directly related to this are environmental impacts which have profound effects on landscapes, water resources, air quality and the communities which rely on them.

This report is a review of best practice greening opportunities for Asian beef supply chains. It includes feed and livestock production; meat processing; value-added and by-products processing; transport and distribution; and finally domestic consumption. Consideration is given to both advanced and less developed supply chains and the issues faced by the actors in these supply chains. The report is expected to serve as a point of orientation for practitioners in their adoption of green industry policies and practices and the improvements that can be made in environmental performance. Where appropriate, a "closed-loop" approach is presented whereby all by-products are recovered and usefully applied to the highest possible level.

The most significant environmental impacts generally occur during the livestock production stage with degradation seen due to greenhouse gas emissions; water extraction and use; land deterioration and biodiversity loss. These are arguably the most challenging to address due to their widespread nature – over half of the world's 500 million small farms are found in China (193 million) and India (93 million) alone (Thapa 2009). Much of Asia's cattle and buffalo population is distributed amongst these farms that support an integrated mix of crop, forage and livestock activities. Intensification of livestock production also arguably exacerbates environmental impacts and has a profound effect on the social fabric of surrounding communities. Greening actions therefore need to take place across the board, taking account of the environmental, social and economic impacts on communities and their surrounding areas.

From a life-cycle perspective, beef livestock production contributes the greatest portion of greenhouse gas emissions across the supply chain, mainly due to enteric emissions (methane) and nitrous oxides from manure. In all, these contribute over 5% of global anthropogenic emissions (MacLeod, Gerber et al. 2012). Opportunities to reduce emissions from livestock include improved feed production and management, breeding methods and manure management. The efficient use of crop by-products and other innovative feed sources, such as urea-molasses-multi-nutrient blocks, would also help relieve the chronic shortage of feed in many regions of Asia. Innovative management techniques such as precision feeding and farming, coupled with technologies such as portable near infrared reflectance spectroscopy (NRIS) and global positioning technologies (GPS) have vast potential for improving production efficiencies, reducing resource use (energy, water, fertilisers) and minimising land degradation and water quality impacts.

Post-farming greening opportunities are potentially easier to manage, given that the impacts can be contributed to point source emissions of greenhouse gases, wastewater and solid wastes. Technological solutions are available to address many of the post-farming impacts. In this respect, the issue is more about the use of appropriate technologies and the ability to continually access finance and training opportunities via capacity building programmes. There are significant opportunities for a closed-loop approach with respect to meat processing. The use of low-carbon energy sources, such as biogas or manure, will not only reduce greenhouse gas emissions, but also help prevent nutrients from polluting water streams. Relatively simple measures, such as improvements in slaughterhouse design and dry cleaning methods will also help separate potentially valuable or useful by-products e.g. blood or paunch manure and prevent them from entering waste streams.

Advances in the supply chain post-farming will come from wider access to refrigeration and extending the cold chain through to retail and domestic consumption. In doing so, more opportunities will open up in the production and sale of value-added meat products and by-products. If existing trends are followed, the increasing demand for meat products will also lead to an increase in waste at the consumer end of the supply chain by as much as 30-40% (Gustavsson, Cederberg at al. 2011). This high level of waste comprises significant levels of embodied energy and water in the final product. Consumer education programmes will become increasingly important in encouraging the efficient use of resources and to minimise waste.

In addition, to reduce environmental hazards associated with a fast-growing meat processing industry, governments need to develop and provide an environmental legislative framework supported by a regulatory system which is implemented and strictly enforced (Heinz 2008, UNIDO 2011). In this respect, international and national standards for hygienic processing and environmental management will play a crucial role in lifting the standards of farming, processing, marketing and distribution of meat products. In areas where regulations are not readily enforced, international corporate companies can exhibit pressure and provide an excellent platform for lifting standards across the supply chain.

Well-thought-out policy is critical for encouraging the development of supply chains and creating opportunities for stakeholders without inadvertently creating adverse environmental impacts. This requires the cooperation, interaction and integration of government and non-governmental agencies, entrepreneurs, industry associations, research bodies, technical associations and suppliers (UNIDO 2011). The availability of well-resourced capacity building programmes is essential. Lastly, the water-energy nexus is an important consideration for all greening policies and associated opportunities, as is a life-cycle approach to ensure impacts are not simply shifted from one part of the life cycle to another.

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1 INTRODUCTION

As part of the UNIDO Green Industry Initiative, the UNIDO-UNEP Green Industry Platform set out to analyse environmental practices in industrial value chains focusing on three selected sub-sectors: the meat industry; the fruit and vegetable processing industry; and the soft drinks industry. The result is a set of best practice compendiums, identifying greening opportunities which can be undertaken along the value chain making the case for less resource-intensive ways of production and recycling. With this, the Platform aims to contribute to its global mandate to accelerate the uptake of green industry policies and practices in high-impact sectors.

This report identifies and showcases best practices in environmental management and resource-efficient production in the meat industry. It shall serve as a point of orientation in the adoption of green industry policies and practices and the improvement of the environmental performance along the value chain and within individual enterprises engaged in it. Greening potentials are identified particularly in the areas of: efficient energy use and generation of energy; reduced water consumption and treatment of contaminated water; air contamination and CO_2 emissions; and waste management. These closely map onto the four priority areas of the UNIDO-UNEP Green Industry Platform, which are: resource efficiency; industrial energy efficiency; water optimisation and chemicals management.

The report is aimed at decision-makers of private sector entities as well as policy-makers interested in exploring the greening potential of the meat industry. The Green Industry Platform will serve as the forum to share the lessons learned among industry associations and governments, and to ensure its wide dissemination.

The report starts from the premise that greening potentials of an industry are best identified in the context of a value chain defined by the flow of products from primary production to consumption, passing through various stages of processing and value addition. For this reason, a value-chain map is introduced at the beginning of the report and the subsequent chapters discuss greening opportunities in various segments (processing steps) of the map.

2 OVERVIEW OF THE ASIAN BEEF SUPPLY CHAIN

Meat supply chains across Asia are extremely diverse with large variations in complexity according to demand and market maturity. Overall, demand for meat products in the region is increasing, fuelled by a burgeoning middle class and the shift from a subsistence lifestyle to one based on consumption. Between 1995 and 2011, in developing countries as a whole meat consumption increased by 25%, while consumption in industrialised countries rose by only 2% (Nierenberg and Reynolds 2012). However, this masks a disparity in individual consumption levels, with the average person in a developing country eating 32.3 kg meat per year compared with 78.9 kg of meat for an industrialised country (Nierenberg and Reynolds 2012). In Asia, most of the meat consumed is pork and poultry, with beef representing approximately 30% or lower of the total meat consumed (Claxton 2013). Japan, Lao PDR, Pakistan and the Republic of Korea have the highest per capita beef consumption, ranging between around 7-15 kg per year. This is followed by China, Malaysia, Taiwan Province of China, Thailand, Viet Nam where per capita consumption ranges between around 2-5 kg per year (Claxton 2013).

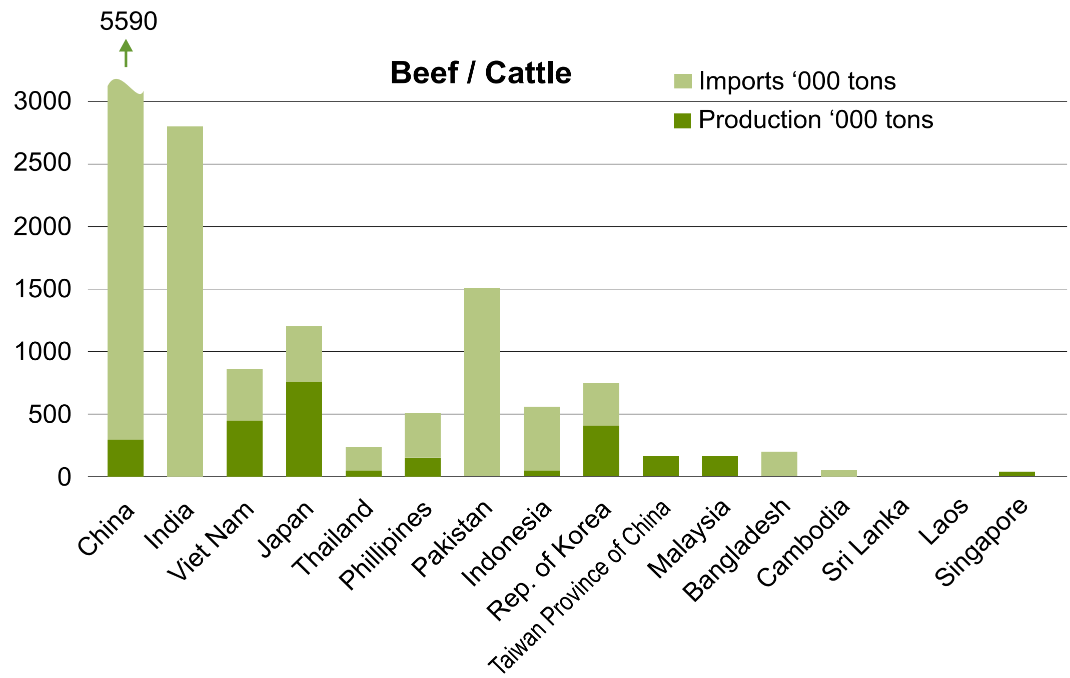

Figure 1: Beef/cattle productions/imports by country, 2011-2013, carcass weight equivalent
(Adapted from (Claxton 2013))

Figure 1 shows beef/cattle production and imports by country. Livestock is generally imported to the least developed Asian countries or those supply chains which do not have sufficient capability to process and distribute fresh or frozen meat products. Australia is currently the largest exporter of livestock, supplying China, Indonesia, Philippines among others (Australian Livestock Exports 2013). Note that there is also substantial cross-border trade of livestock between Asian countries, both legal and illegal (FAO 2013).

In 2012, India took over as the world's largest beef exporter followed by Australia, Brazil, the United States, New Zealand, Canada, the European Union (EU), Uruguay and Argentina (Beef Central 2012). For India, beef exports are in the form of frozen or chilled buffalo meat (as opposed to cow meat) with greatest demand coming from Malaysia, Philippines, Thailand and Viet Nam

Wholesale beef market in Mumbai (Gosh 2012)

(APEDA AgriXchange 2013). China's demand for beef is growing with the greatest percentage of imports (chilled beef products) being sourced from Australia (MLA 2013). Demand for US and European products has been affected by health and safety related issues such as outbreaks of bovine spongiform encephalopathy ("mad cow" disease) (FAO 2011, Nierenberg and Reynolds 2012, Giamalva 2013) and aphthae epizooticae (foot-and-mouth disease). Countries, such as Australia and New Zealand, which are able to promote a clean, green product, can demand premium prices. Japan is the biggest importer of premium grade (frozen/chilled) beef in the Asian region (Figure 1).

Across Asia, modern supply chains exist alongside and integrate to varying degrees with traditional supply chains such as farmer/traders, wet markets, small independent stores and ubiquitous street vendors (Gomez and Rickets 2012) cited in (FAO 2013). In traditional supply chains, consumers in rural and urban areas typically buy most of their meat from small independent retailers. Meat is typically sold at roadside stands and open markets. Fresh meat supply usually comes directly from farms in relatively close proximity to these markets. As food systems develop, wet markets may continue to be prevalent, but larger stores with a wider range of goods will replace the smaller kiosks (FAO 2013) and supermarkets have begun to appear in the larger cities (Reardon and Timmer 2012) cited in (FAO 2013). In most developing countries, including China and India, the spread of supermarkets started later with the corresponding food retail share typically less than 50% (Reardon and Gulati 2008). Integration between modern and traditional channels is therefore a key part of a corporate strategy.

It is also noteworthy that the middle classes in Asian emerging markets are not concentrated in the big cities. In China, middle-class consumer groups in smaller cities are growing at a faster rate than their counterparts in first-tier cities such as Beijing, Shanghai and Guangzhou, while the Indian middle classes are scattered around the country (Andrew and Peng 2012). This has an impact on supply chains, particularly in ensuring a hygienic and safe product reaches the consumer.

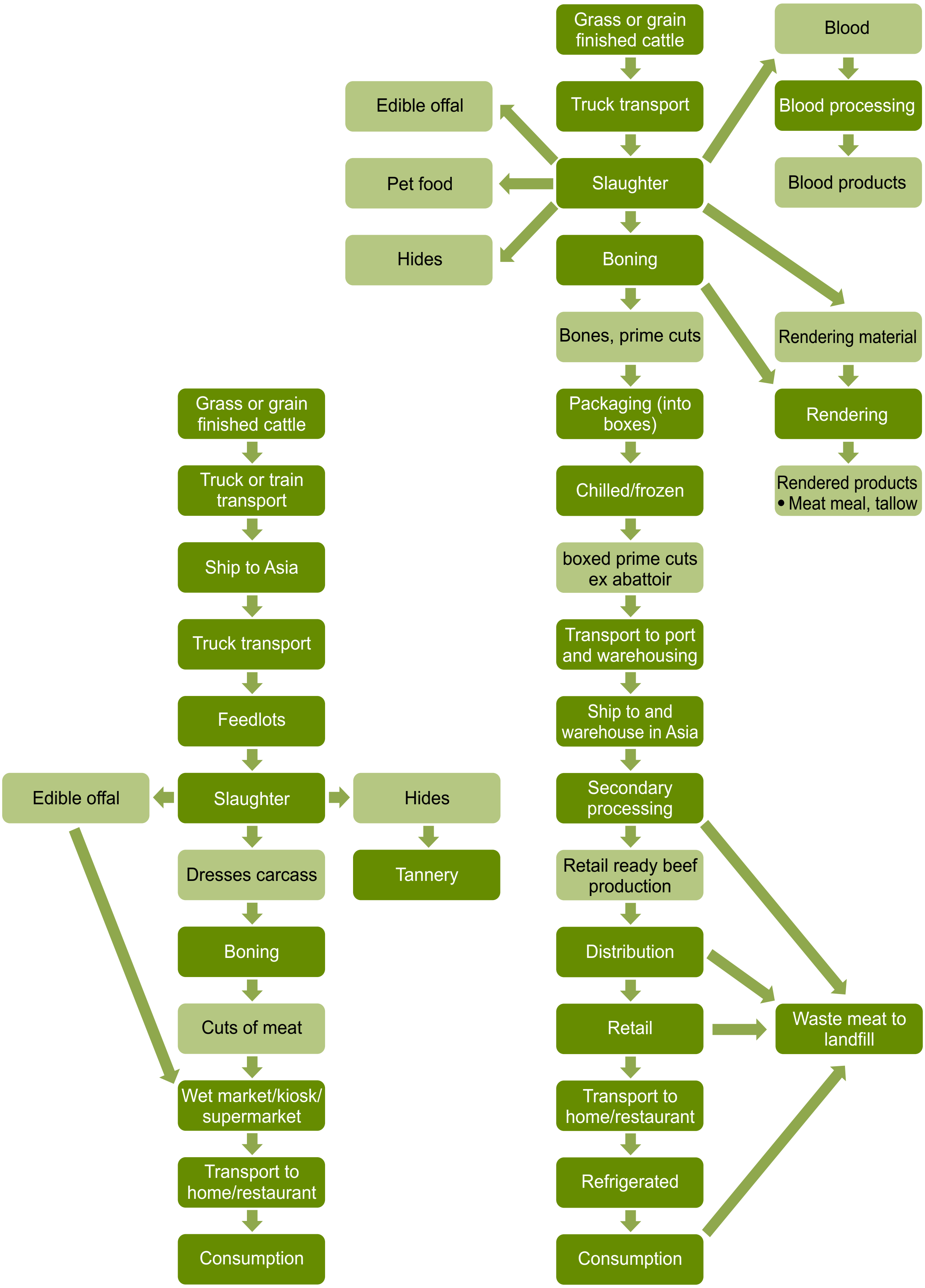

Figure 2: Basic supply chain - Live cattle imports and limited refrigeration

Figure 3: Advanced supply chain - import of boxed beef and access to refrigeration

Figure 2 and Figure 3 map two typical supply chains for beef in Asia – the first shows the chain for livestock imports and the second is that for imports of boxed chilled or frozen products. Another variation on the supply chains shown is that of locally bred cattle which are is processed, distributed and sold via more traditional channels that may or may not have access to refrigeration.

Meat processing facilities vary between small-scale backyard farmer/butcher concerns to large-scale modern production facilities. Japan, Malaysia, and the Republic of Korea have some of the most modern production in the region, with standards that would be comparable with western producers, although often at a smaller scale (Claxton 2013)

3 LIFE-CYCLE IMPACTS OF BEEF SUPPLY CHAINS

Life-cycle assessment (LCA) studies are undertaken to determine environmental impacts of a product across an entire supply chain (cradle-to-grave) or in a selected section of the chain. They highlight "hotspots", thus enabling efforts to be focused where they are most needed. They also allow impact-reduction strategies to be analysed to ensure impacts are not simply shifted from one part of the life cycle to another.

Most LCA studies have been undertaken on beef supply chains in Australia, the US and Europe, not all of which are available for public reference. The boundaries for many of these studies have included livestock production, feedlots and processing, with fewer studies including upstream impacts of land use and downstream impacts of retail distribution and consumption. A wide range of impact indicators can be assessed (Harris and Narayanaswamy 2009), but the most common of these are greenhouse gas (GHG) emissions and energy use, and to a lesser extent water and waste impacts. Depending on the indicator assessed, some general conclusions can be taken from these studies and these are discussed below. However, strict procedures/care must be applied in making comparisons between studies (Harris and Narayanaswamy 2009, Rowley et el. 2010). Direct comparisons of impacts and resource use cannot be made without due consideration of system boundaries, methodologies and functional units, as well as quality and quantity of data sources.

3.1 Greenhouse gas emissions

Livestock production is a key contributor to anthropogenic greenhouse gas GHG emissions (FAO 2009, Peters, Rowley et al. 2010) in the form of carbon dioxide (CO_2), methane and nitrous oxide (N_2O) gases. Emissions vary depending on the mode of production and intensity e.g. pasture versus feedlot, as well as feed conversion rates (Peters, Rowley et al. 2010). Land use for livestock production also contributes to the release of large quantities of carbon dioxide through land degradation and loss of forests and other vegetation for grazing lands and feed crops. Estimates by various sources, including the Intergovernmental Panel on Climate Change (IPCC), the US Environmental Protection Agency (EPA) and the Food and Agriculture Organization of the United Nations (FAO), place livestock contribution to global anthropogenic GHG emissions at between 7 and 18% (FAO 2009).

Of all livestock production, beef farming has the highest emission of GHG mainly due to enteric emissions (methane) (Mogensen, Hermansen et al. 2008, Leip A, Weiss F et al. 2010, Peters, Rowley et al. 2010) and this contributes over 5% of global anthropogenic emissions (MacLeod, Gerber et al. 2012). LCA studies of beef supply chains have indicated that GHG emissions from farming and feedlots are in the order of 85% of total emissions produced from farming, feedlots and processing (Peters, Rowley et al. 2010). However, most beef LCA studies have not included the impacts of land use and land use change (Ridoutt, Sanguansri et al. 2011, Schmidinger and Stehfest 2012, Weiss and Leip 2012). Example calculations for several livestock products (including beef) show that the missed carbon sequestration potential due to land use or change can be in the same order of magnitude as the other process-related greenhouse gas emissions of the LCA, and depend largely on the production system (Schmidinger and Stehfest 2012). Across meat supply chains, greenhouse gas emissions resulting from transport (including to export markets) are shown to be of lower significance compared with livestock production (Mogensen, Hermansen et al. 2008). Emissions from processing, transport, packaging, retail, consumption and waste of the products, usually make up about 10–20% of total emissions (Weiss and Leip 2012).

3.2 Energy

For well-developed supply chains, where retail meat cuts are sold frozen or chilled and then stored in home refrigerators, studies indicate that the sector responsible for highest the percentage of energy consumption is households, followed by meat processing (Canning, Charles et al. 2010). For households, this can be attributed to a loss in economies of scale for the storage and cooking of meat. In meat processing, most energy is consumed by refrigeration systems along with other utilities, such as boilers. One review shows this to be in the order of 60-65% for studies including farming, feedlots and processing (Peters, Rowley et al. 2010). Those supply chains which include small basic slaughterhouses supplying local wet markets would be expected to show a smaller percentage of energy use during the processing stage and perhaps a proportioned high level of energy use during the domestic consumption stage.

3.3 Water

LCA results for water use across beef supply chains are extremely variable and dependant on the method adopted for determining water use, the local climate, the type of animal stock, feeding regimes (pasture or grain), feed production (irrigated or not) and many other factors (Peters, Wiedemann et al. 2010, Ridoutt, Sanguansri et al. 2011). For this reason, no general comments can be made regarding water use across beef supply chains. Globally, the majority of beef cattle are raised in non-irrigated mixed farming and grazing systems. Therefore, the general assertion that meat production is a driver of water scarcity is not supported (Ridoutt, Sanguansri et al. 2012). The variation in water footprint across beef supply chains and the use of standard methodologies needs to be explored further. However, it must be stated that grain and fodder for lot feeding is generally dependant on irrigated water supply, thus increasing total water demand as meat demand increases. Also slaughterhouses are – and certainly should be – large individual consumers of water that should be of highest quality for hygienic purposes as well as other production plant needs. Thus abattoirs can often impose a high local water demand that can often be unchecked and is amenable to best practice minimisation methodologies.

3.4 Energy-water nexus

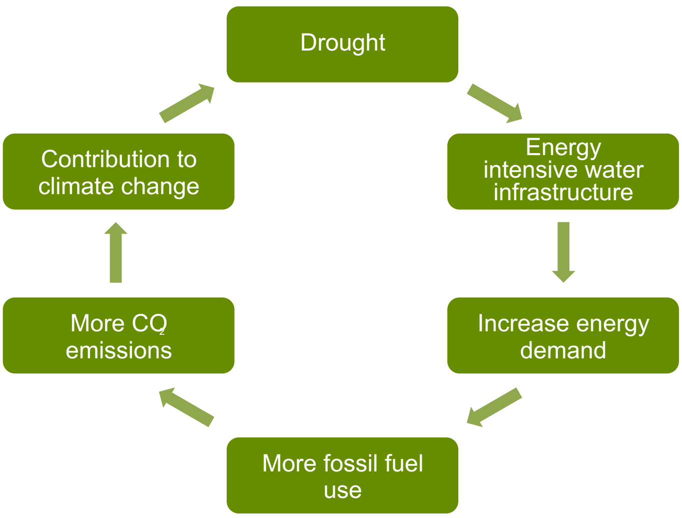

Figure 4: Energy-water nexus vicious cycle (adapted from (Retamel, Turner et al. 2009))

The water-energy nexus is also important for Asia, particularly those dryland countries subject to drought, such as Afghanistan, China, India and Pakistan. The treatment and supply of water to communities and industry is energy-intensive, while traditional fossil fuel (coal) based energy generating technologies are water-intensive. The generally increasing demand for energy and water, the impact of climate change and the interrelationship between all of these factors creates a vicious circle (Figure 4). Any strategies to reduce water or energy use should also be analysed in light of the effect along the supply chain and on other resources. Life-cycle studies play an important role in this respect.

3.5 Waste

The use of refrigeration across a supply chain plays an important role in increasing the availability of meat and the capacity to deliver hygienic, safe meat products to consumers. It also leads to variation in the distribution of waste. A report by Gustavsson et al (Gustavsson, Cederberg et al. 2011) highlighted that, 'in all developing regions losses are distributed quite equally throughout the supply chain, but notable are the relatively high losses in agricultural production in South and Southeast Asia (Figure 5). This is explained by high animal mortality, caused by frequent diseases (e.g. pneumonia, digestive diseases and parasites) in livestock breeding'. As shown, only 5–15% of food losses occur at the consumer level in the developing regions considered, compared with 30–40% in the developed regions. Losses in industrialised Asia are also in line with other developed regions (Figure 5). The variation is most likely related to the lack of refrigeration at the consumer level in developing regions.

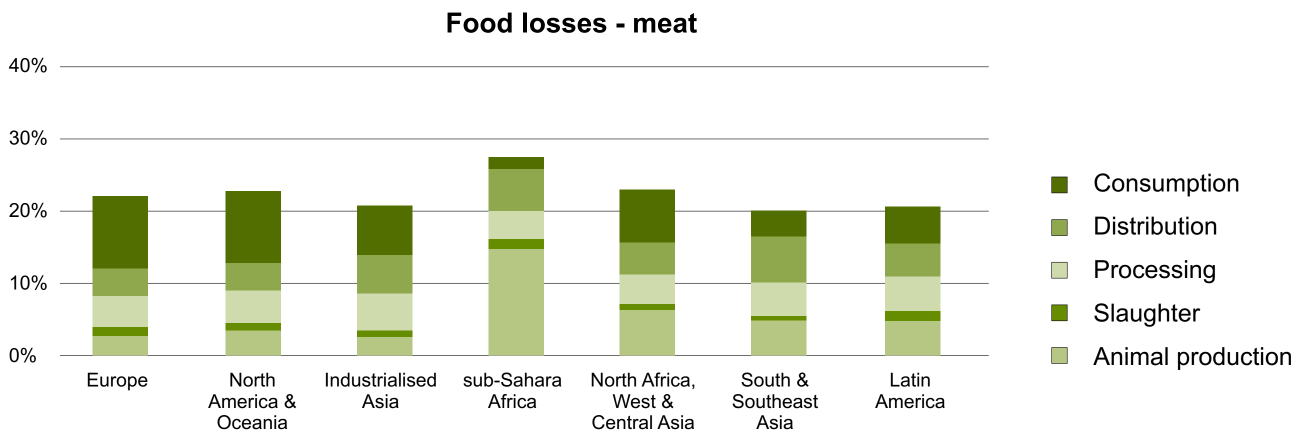

Figure 5: Meat losses across the supply chain

(Gustavson, Cederberg et al. 2011)

4 GREENING IN LIVESTOCK PRODUCTION

4.1 Overview of beef production systems in Asia

Many of the world's 500 million small farms are found in Asia, with over half in China (193 million) and India (93 million) alone (Thapa 2009). Much of Asia's cattle and buffalo population is distributed among millions of these small farms that support an integrated mix of crop, forage and livestock activities. Greening action needs to take place throughout the entire system in a way that takes account of the environmental, social and economic impacts on communities and the areas that surround them. A simple production chain is shown in Figure 6.

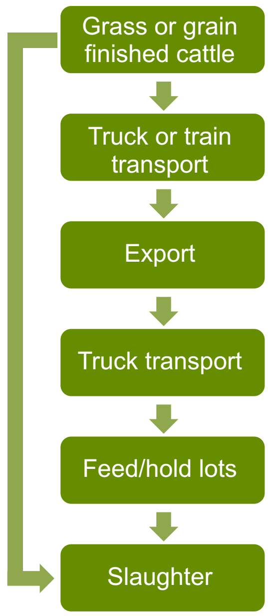

Figure 6: Livestock production chain

Traditional beef production systems are characterised by a "low-input/low-output model" (Singh 2011) based on low- or no-cost feed. Feed sources include crop stubble, native pastures and sown forages. Livestock are tethered, grazed or penned and hand-fed a mixture of cut-and-carry agricultural waste, pastures and shrubs. In return, they offer a source of stored wealth, draught power and manure to fertilise crops. Stock is sold directly at cattle markets or via a village collector. Production is increasingly constrained by low breeding-herd productivity and scarcity of readily available forage (Hadi, Ilham et al. 2002). Intensive cropping for both human and livestock feed has double or even triple cropping intensity and such systems have removed much of previously available fallow lands for grazing. With rapid economic and income growth, urbanisation and globalisation, production is also intensifying with land use for high-value meat becoming as, or more, important than traditional modalities (Thapa 2009). Smallholders close to feed sources and consumers in peri-urban areas increasingly fatten livestock for sale at local markets with purchased feedstuffs. These can be by-products of crop processing, such as molasses, maize gluten, and brewery grains; oil meals and cakes, such as copra, linseed, and palm kernels; milling by-products, for example cereals and pulses; dried roots and tubers e.g. cassava; and industrial products such as urea (VDEPI 2011), in others words whatever is cheap, nutritious to varying degrees and available.

Some intensive industrial systems which use large quantities of good-quality forage and concentrate, and which closely manage animal health and nutrition, have also emerged in urban areas close to processing facilities and markets. In some cases, governments promote partnerships between private institutions and small growers where the venture provides feeder cattle and cash for purchasing feeds, vaccines and other medicines (Hadi, Ilham et al. 2002). In areas unsuitable for cropping, cattle and buffalo are still grazed extensively, often by nomads or marginal farmers.

In South Asia, mixed crop and livestock systems dominate the region extending from the Himalayan ranges through to southern India. This includes rain-fed crops in central and southern-most humid areas and irrigated crops in western dry areas. Most of Afghanistan, north-west India and Pakistan is made up of arid and semi-arid areas where nomadic pastoralists graze stock on communal land and use crop residues from scattered irrigated and rain-fed crops. Similarly, nomadic pastoralism dominates semi-arid and arid areas of western China and central/northern Mongolia, with opportunistic grazing in southern Mongolia (Dixon, Gulliver et al. 2001). On the lowlands of the Himalayan range, rice-wheat systems extend from northern Pakistan to Bangladesh, producing the bulk of food grains for urban areas. In these systems, livestock still play an important draughting role (Dixon, Gulliver et al. 2001). Mixed cropping and livestock systems are found on the upland and hill landscapes of central-east China and much of Southeast Asia. Here stock is kept on flatter, predominantly rice-based cropping areas of south and central-east China, Indonesia, Myanmar, Philippines, Thailand and Viet Nam. Industrial fattening operations have been established in Indonesia, Japan, Malaysia, Philippines and Viet Nam with domestic feeder cattle supplied through northern Australia's live cattle trade (large, consistent lines of cattle that are free from foot-and-mouth and other disease and meet the tight specifications for feedlot entry) (Hadi, Ilham et al. 2002).

4.2 Intensification of beef production systems

The vast majority of extensive grazing land in Asia is of low productivity (Springfeld, Geber et al. 2006) and is incapable of meeting growing urban demand in terms of both quality and volume. It is therefore inevitable that the continuing trend towards intensification and industrialisation will continue. Production shifts are likely to marginalise small, remote rural landholders and pastoralists while also leading to localised concentrations of nutrients and waste. The relative impacts of extensive and intensive livestock production systems on the environment are detailed in FAO's *State of Food and Agriculture Report 2009 (*FAO 2009) and shown in Table 1. Strategies to address some of these impacts are discussed in the following sections.

Table 1: Major impacts of extensive and intensive livestock systems

(FAO 2009)

Impact (- negative, + positive, ns = not significant)	Extensive grazing	Intensive systems
Greenhouse gas emissions		
CO_2 emissions from land use and land use change for livestock production	- - -	-
CO_2 emissions from energy and input use	ns	- -
Carbon sequestration in rangelands	+++	ns
Methane emissions from digestion	- - -	- -
Nitrous oxide from manure	-	- - -
Land degradation		
Expansion into natural habitat	- - -	ns
Overgrazing (vegetation change, soil, compaction	- - -	ns
Intensive feed production (soil erosion)	ns	- -
Soil fertilisation	+	+
Water depletion and pollution		
Alteration of water cycle	- -	-
Pollution with nutrients, pathogens and drug residues	ns	- -
Biodiversity		
Habitat destruction from feed crop production and animal waste	- - -	-
Habitat pollution from feed crop production and animal waste	ns	--
Loss of domestic animal genetic diversity	ns	--
Ecosystem maintenance	++	ns

The World Bank and FAO support the integration and decentralisation of stock and cropping activities. Integration avoids issues of land allocation for unaffordable waste treatment systems and maintains social benefits of supporting local rural development. It also encourages recycling of livestock waste on crop lands without overloading soils and freshwater systems (Springfeld, Geber et al. 2006). Payment for environmental services such as watershed services, biodiversity conservation and carbon sequestration has been successful in some areas (Box 1). For those systems that cannot be decentralised, zero-emission policies, coupled with close regulation of point source emissions, need to be introduced - examples of such policies include biogas production and/or fertiliser production from manure.

Box 1: Payment for environment services - Central and South America
(FAO 2013)

Between 2003 and 2006 cattle farmers from Colombia, Costa Rica and Nicaragua, received between US$ 2,000-2,400 per farm (10-15% of their net income) to implement silvopastoral systems. The project led to a 60% reduction in degraded lands, a 71% increase in carbon sequestration and an increase in farm income of 115%.

4.3 Greenhouse gas emissions

Producing 5% of global anthropogenic greenhouse gas emissions (MacLeod, Gerber et al. 2012), the beef production industry generates significant GHG emissions directly from enteric fermentation and manure management and indirectly from feed production (Table 2). There are opportunities to reduce emissions through feed and feed management, breeding, and manure management. Further opportunities are discussed in the water and rangeland management sections of this report.

Table 2: CO_2 equivalent emissions from beef livestock 2011

(FAO 2011)

Region	CO_2 eqiv. emissions (Gg)	Buffalo	Non-dairy cattle
Eastern Asia	Enteric	27 261	78 953
	Manure management	5 775	16 934
	Applied manure	945	3 061
	Pasture manure	6 903	19 079
South-Eastern Asia	Enteric	17 273	43 222
	Manure management	3 973	9 270
	Applied manure	599	1 676
	Pasture manure	4 374	10 444
Southern Asia	Enteric	172 511	128 959
	Manure management	18 205	2 874
	Applied manure	1 201	821
	Pasture manure		18 255

4.3.1 Feed systems and management

Asia has a chronic feed shortage and will need to enlarge and efficiently use indigenous feed resources to not only lower emissions but to decrease reliance on trade and vulnerability to cost fluctuations (Makkar 2013). Greening opportunities can help to ensure inadequate feed supply is not the result of poor feeding management practices. The following practices reduce overall emission intensity through productivity enhancement.

Box 2: Local forage inventories used to develop efficient feed fattening diets – Viet Nam
(Leddin, Ba et al. 2011)

An economic analysis in the Quang Ngai province indicated attractive returns on cattle fattening, however barriers included limited farmer knowledge on cattle nutrition, general low-quality forages of limited availability and inefficient use.

A project involved developing an inventory of forages and energy supplements available at the household level throughout the year and their nutritive characteristics. From this, optimal combinations of feed were identified and trialled. Traditional fattening of rice straw supplemented with native or sown grasses supported a growth of 0.1kg/day. Farmers reported that the recommended addition of a concentrate, such as cassava powder, maize, or rice bran, improved live weight gains. A number indicated their full adoption was dependent on supplements being subsidised.

Feed sources

National Feed Inventories (type, quantity, availability and nutritional value) are useful in helping to understand how many animals can be sustainably produced on existing feed resources and what feed resources and markets could be developed (Makkar 2013). This requires investment into methodologies including the use of databases, geographic information systems (GIS), remote sensing and modelling (Coughenour and H. 2012). At a local level, feed inventories to assist producers to develop year-round feeding options and improve understanding of animal nutrition is crucial (Box 2). Alternate feed sources need to be identified, such as crop residues for the production of feed blocks that would be otherwise burnt (Makkar 2013) (Box 3, Box 4 and Box 5).

The inclusion of concentrate (high-density nutrients) in diets greatly assists productivity and potentially has a low to medium methane mitigating potential (Gerber, Hristov et al. 2013). However, there is debate over the quantity of absolute emissions if grain growing and manure management is included (Hristov, Oh et al. 2013). The inclusion of **protein-rich legumes** in feed supplies nitrogen to agro-ecosystems and uses 35-60% less fossil energy than nitrogen-fertilised crops, reducing emissions related to fertiliser use (Jensen, Peoples et al. 2012).

Box 3: Waste streams could be economically viable sources of lipids – Australia
(VDEPI 2011)

In Australia, 200,000 tons of grape waste is produced each year, with the bulk ploughed back into the soil and a small amount used in feedlots. A trial group of cattle were fed the stems, seeds and skins from wine grapes made into pellets or silage (grape marc) with crushed wheat grain and lucerne hay. Grape marc contains unsaturated fatty acids as well as tannins which are known to reduce methane production in cattle but more long-term studies are required. The 4% increase in fats resulted in a 14% reduction in methane emissions.

Box 4: Sugar cane silage found to be a suitable basic diet for beef cattle – Thailand
(Suzuki 2006)

The northeast is Thailand's biggest region of beef cattle production with most animals raised on small, mixed farms. The shortage of forage in the dry season, however, limits production due to difficulties in long-term preservation of hay and silage produced from local Pangola. Trials have shown that these difficulties have been overcome through use of sugar cane silage.

Box 5: Straw-based densified total mixed ration blocks from crop residues (DTMRBs) – India
(Walli, Garg et al. 2012)

As a result of “green revolution” in India the availability of dry matter through crop residues has increased by 85% since the eighties, with 6.6 million tons in CO2e- released annually from burning crop residues (INCCA 2010). An alternative is to collect the straw to make feed blocks. Benefits of the use of DTMRBs include:

- a reduction in emissions of 10–15% as a result of a balanced diet (Garg and Bhanderi 2011);
- reduced emissions from avoided burning of crop residues;
- prevention of selective feeding and increase in straw palatability;
- time and labour saving, especially for women;
- one-third less volume needed for storage;
- cheaper and easier to transport and less dust;
- suitability for feed banks in the case of natural or manmade disasters or in feed deficit areas; and
- less price fluctuations and a regular supply.

Feed management

Proper feed management can increase productivity whilst also reducing emissions. For example, **forage quality and management** has low to medium methane-mitigating potential depending on forage species, composition, age and preservation methods. It is important that levels of crude protein associated with forage do not exceed the needs of the animal, otherwise N_2O emissions may increase. **Rotational grazing** allows for the more efficient conversion of forage into meat with reductions in methane as high as 22% (Gerber, Hristov et al. 2013). **Silage making** in Asia is essential in areas with shortages of feed during the dry season but often plentiful forages in the wet season. Methane emissions can be reduced when legume and corn silages replace grass silage however any change in land use must consider the total carbon footprint, especially if fertiliser inputs will increase (Hristov, Oh et al. 2013).

The use of proper **post-harvest technologies** can help prevent waste. For example, the elimination of fungal infestations in feed (aflatoxin) prevented losses in the order of US$900 million per year in Indonesia, Philippines and Thailand (Makkar 2013). **Forage particle reduction** increases digestibility and productivity. Yang's study showed that processing of barley grains using roller settings to achieve uniformity in kernels improved feed conversion rates with cattle leaving the feed lot 25 days earlier and saving 163kg of feed per animal (Yang, Oba et al. 2012).

The adoption of science-based **precision feeding and feed analysis systems** is considered to be essential in improving productivity in Asia (Hristov, Oh et al. 2013). Technology such as near infrared reflectance spectroscopy (NRIS) can be used by feed laboratories or suppliers to avoid waste. Feeds can be over formulated by as much as 7.5% to compensate for variation in nutrient delivery (van Kempen and T. 1997). The safety margin can be reduced using NIRS to acquire accurate real-time analysis of the feed ingredients (Szabo and Halas 2012). Examples of the benefits of proper diet formulation have become evident in Asia's dairy industry. Box 6 describes the use of ration balancing programme software that could be applied to the beef cattle industry.

Box 6: Ration balancing programme software – India
(Garg 2012)

The computer programme comprises a feed data library (feed data collected from different agro-ecological areas analysed for chemical and nutritional value) and various national and international feeding standards for nutrient requirement of growing, lactating and pregnant animals. The daily feed intake, milk yield and milk fat percentage of 3,100 animals from 50 villages were recorded. The software then formulated least cost ration using locally available resources. Producer incomes increased by 10-15% and milk production efficiency by 34%. Enteric methane emissions from a balanced diet were reduced by 10-15% per kilogram.

Box 7: Locally produced urea-molasses-multi-nutrient block–Pakistan
(Khanum, Hussain et al. 2010)

Livestock feed in Pakistan is based on low-quality roughages. Solidified urea-molasses-multi-nutrient block (UMMB) produced with locally available low-cost ingredients have been shown to reduce methane emissions by improving digestibility, feed intake and weight gain. Many farmers are convinced of the benefits and this technology is rapidly becoming popular although inadequate resources and unavailability of molasses in certain parts of the country restrict its scope.

Feed additives

The following examples of feed additives have been shown to reduce GHG emissions:

- **Nitrate supplementation** such as urea molasses multi-nutrient lick blocks and ammonia and urea straw treatment can have a high methane-mitigating potential. The uptake of treating straw with urea has been poor as a result of insufficient urea supplies, the cost of urea, myths around the impact of urea and difficulty at the village level in using the technology (Chander 2010) (Box 7).
- **Dietary lipids** have a high methane-mitigating potential with a 10-25% reduction achievable (Beauchemin, Kreuzer et al. 2008). However, inclusion is not always economically viable.
- **Ionophores** are carboxylic polyether antibiotics that have a moderate methane-mitigating potential by modifying the rumen microflora and improving nitrogen use. They are commonly used in the US, but banned in the EU due to fears of antibiotic resistance spread via the food supply chain (The Poultry Site 2005).

4.3.2 Breeding

Genetic improvements can be a cost-effective means of bringing about permanent and accumulative reductions in emissions (Scollan, Moran et al. 2010). It is particularly useful for extensively managed cattle where the application of regular "input" strategies is not practical. Rates of genetic change, however, are often substantially lower than what is theoretically possible as breeding is often highly dispersed. Some examples are discussed below:

- **Genetic selection for greater productivity and environmental adaptability** has a high methane-mitigating potential (Hristov, Oh et al. 2013). Breeding in the future is likely to include molecular genetics (Box 8) and the selection of traits that are more highly correlated with methane emission levels such as feeding efficiency (Hayes, Lewin et al. 2013). Trait selection in Asia has been influenced by sale prices, often based solely on the weight of the animal and phenotypic traits, such as coat colour, which can have cultural significance (IAEA 2009).

Box 8: Molecular technology to assist in the selection of difficult or expensive genetic traits that may help to reduce methane emissions (Hayes, Lewin et al. 2013)

DNA-based tests for genes or markers affecting traits that are currently difficult or expensive to measure will be particularly useful. The advantage of DNA selection over traditional phenotype breeding is that genetic information can be available at an early age thus eliminating emissions arising though empty reproductive cycles or involuntary culling (Scollan, Moran et al. 2010). This technology has been well adopted by the dairy industry where genome selection is expected to double the rate of genetic gain (Hayes, Bowman et al. 2009).

DNA profiles are also being developed for microbiomes in the rumen. This will be an important tool in understanding how microbes affect feed conversion-efficiency and methane emissions. Promising research includes the possibility of developing a vaccination of antibodies (Leahy, Kelly et al. 2013).

- **Crossbreeding** can have a high methane-mitigating potential. Exotic, non-adapted animals used in crossbreeding in Asia have generally failed to deliver and in recent years the approach has been to cross suitable non-adapted animals with indigenous breeds (Hristov, Oh et al. 2013). This practice is encouraged as guidelines developed for selection and breeds in Asia suggest there is an urgent need to conserve the uniquely adaptable, heat tolerant, drought and disease resistant local breeds (IAEA 2009).

- **Reducing the age at harvest and reducing days on feed** has a medium methane-mitigating potential e.g. less time on poor pastures prior to fattening (Government of Alberta 2011).

- **The use of artificial insemination to improve production** traits reduces the number of herd bulls required (reducing feed needs) and improves the genetics for replacement heifers. Shorter and more consistent calving is possible, saving time and money (Angus Lawson 2012).

4.3.3 Manure management

Manure is a valuable resource that can reduce the use of energy-intensive chemical fertiliser. However, if mismanaged, manure can lead to significant emissions, odours, health risks and nutrient loss through soil leaching and runoff. Emissions of gaseous nitrogen compounds can be lowered when manure is collected immediately following deposition (for housed cattle) and treated anaerobically in lagoons with covers (popular in warm climates) or closed tanks. The methane can be captured and flared or used as a source of energy for cooking, lighting or electricity generation. This not only reduces the impact of methane, ammonia, nitrous oxide emissions and odours (Oenema 2006) but can offset CO_2 emissions from burning fossil fuels. The solid fibrous component of the digested material can be used as a soil conditioner to increase the organic content in soils while the digester liquor can be irrigated as fertiliser to replace the use of mineral fertilisers and their associated carbon intensive footprint (Box 9).

Nitrous oxide emissions can be reduced through best practice manure applications to avoid runoff, crop damage and soil contamination. This is particularly significant for industrial beef production systems applying high volumes of manure to surrounding rural areas. With Asia being the leading user of mineral fertiliser globally (57% of the world's nitrogen consumption and 54.5% of the world's phosphorus) (Springfeld, Geber et al. 2006) there is significant scope to reduce industrial fertiliser use.

Box 9: Kolar biogas project – India
(myclimate – The Climate Protection Partnership 2012)

SKG Sangha is an Indian NGO, which has successfully implemented over 100,000 biogas units in India over the last 18 years. They are currently installing domestic biogas plants in around 10,000 rural households in Karnataka State.

The digesters will be fed with cattle and buffalo dung and kitchen wastewater. The gas generated will be used for cooking while the slurry will replace the use of mineral fertilisers. The project will also help to reduce fuel wood, thus protecting scarce forest resources while also reducing air pollution from traditional wood cooking stoves and time spent collecting wood. The project is expected to reduce GHG emissions by 546,000 t CO_2e over the next 10 years.

4.4 Rangeland management

Rangeland management aims to ensure a sustained yield of rangeland products while protecting and improving soil, water, and biodiversity. China has 400 million hectares (ha) of rangelands (41.7% of land area) of which 313 million ha can be grazed. It is the second largest area of rangeland in the world after Australia (Ren, Hu et al. 2008). Rangeland degradation rose from 55% of land area in 1996 to over 90% in 2006 as a result of overpopulation, the introduction of intensive grazing and rain-fed techniques of forage and fodder production, privatisation, sedentarisation of nomads and drought (Lu, Fan et al. 2006). In Mongolia, rangelands cover 112.8 million ha (72% of land area) (Jamsranjav 2009). It is estimated that about 70% of these pasture lands have become degraded (Mongolian Society for Range Management 2010) over the past two decades due to extreme weather events and unrestricted herding access.

Conservation of these rangeland areas is significant, not only because they are the headwaters for many of Asia's major rivers, but also for their globally recognised biodiversity. In recent decades traditional nomadic practices such as rotational grazing and resting have been undermined. It is beneficial for herder communities to participate in herding policy and share herding tasks (Box 10).

Livestock mobility and flexibility is the key to rangeland pastoralism and a response to

Box 10: Rangeland carbon sequestration project – Qinghai, China
(Huang 2013)

The Three Rivers Grassland project (launched in 2009) aims to break the cycle of overstocking and degradation by demonstrating sustainable management options and sequestering over 500,000 t CO_2e over 10 years. Herders were offered a menu of options designed to fit their specific land use including:

- improving the seasonal rotation of grazing animals thereby limiting the time and number of grazing animals on degraded pastures;
- restoring severely degraded lands by replanting with perennial grasses; and
- improving animal production via feeding, winter housing and breeding.
- Herders will have fewer but more productive livestock with incentives to increase numbers once productivity is raised.

The project is expected to overcome key barriers such as access to carbon finance; development of appropriate methodologies for determining carbon credits; and access to cost effective monitoring, reporting and verification.

this unpredictable ecosystem. Forage maps and early warning systems can assist timely and informed decisions regarding sustainable stock numbers in the light of seasonal forecasting and availability of pastures (Box 11). Options include sending stock to fattening facilities in lean periods however many herders have limited access to these types of facilities and local breeds can be less responsive to intensive feeding. An analysis of China's mitigation options found that with an abatement potential of 80 million tons of CO_2, grassland management and restoration was the most important abatement opportunity in China's agriculture up to 2030 (McKinsey & Company 2009). As the economic value of carbon sequestration becomes increasingly recognised and quantified in the global marketplace the value of rangelands as carbon sinks is expected to rise. Adoption has been hampered by an inadequate information base for accurately quantifying mitigation potential (Abberton, Conant et al. 2009). A methodology based on the Three Rivers Grassland Carbon Sequestration Project in Qinghai Province, China was developed in 2011 for the adoption of sustainable grassland management (Box 10).

Box 11: Early warning system for livestock - Gobi region of Mongolia
(Center for Natural Resource Information Technology 2013)

Between 1999-2002, 50% of livestock were lost in the Gobi Region due to drought. A Livestock Early Warning System has since been adopted. The technology combines near real-time weather, computer modelling, and satellite imagery with 297 monitoring sites and nutritional profiling technology to produce regional maps of current and forecasted forage conditions. These are regularly delivered to herders using various media.

Herders can also scan their stocks animals' faeces with a portable NIRS machine. This determines what forage or supplements can be fed to the animal to allow it to maintain weight or nurse offspring. A laboratory has been established and a mobile laboratory is being tested to allow this technology to be brought directly to herders. Over 70% of herders are familiar with the products with 50% having used the information to guide livestock movements (51%), provide supplemental feed (49%) or change their rotational grazing strategy (40%).

4.5 Water conservation and quality

It is predicted that by 2025, 64% of the world's population will live in water-stressed basins (Rosegrant, Cai et al. 2002) while 33% will live in areas of absolute water scarcity, including Pakistan and regions of India and China (International Water Management Insitute 2000). While the area for extensive grazing is not expected to increase significantly, the expansion of intensively managed mixed farms and industrial livestock systems will require more feed and feed transport. It is expected that 80% of crop growth will occur in developing countries through increased yields and higher cropping intensities. By 2050, increasing food demand will require South Asia to irrigate 30% more harvested land resulting in an increase in demand for water of 57% unless water efficiency improves. In East Asia the amount of irrigated farmland would need to increase by 47%, with an increase of 70% in water use (Block 2013). This is concerning given that Asia already has 70% of the world's irrigated area (International Water Management Insitute 2010). Along with dams and storage structures built in the 1950-70s, millions of smallholders have now created their own mini-irrigation systems. For example, in India over 60% of irrigated areas today are under atomistic pump irrigation that scavenge surface and ground water (Faures and Mukherji n.d.). This rise in individual irrigation efforts may further deplete resources with countries struggling to regulate this practice. Combating the water crisis in Asia will involve catchment-level development and management with cooperation from all stakeholders.

Beef production plays a role in degrading freshwater systems. Soil degradation and erosion as a result of overgrazing and poor soil management in feed production causes the mobilisation of nutrients (in particular nitrogen and phosphorous from manure and mineral fertilisers) and pollutants, as well as increased sedimentation that obstructs waterways, destroys aquatic and reef ecosystems and disturbs natural hydrology. Initiatives to avoid the degradation of water systems include:

- ensuring sustainable stocking rates and grazing management (Trimble and Mendel 1995);
- manure management and treatment (Springfeld, Geber et al. 2006);
- fencing projects and off stream water points to keep stock away from riparian areas; and
- revegetation and weed management of remnant vegetation and waterways.

There are numerous initiatives for minimising water consumption and withdrawals during growing of feed. An important initiative is conservation tillage, which leaves at least 30% of the crop residue on the soil surface, helping to improve soil structure and water retention. It also reduces the use of fertiliser, pesticide and fuel, while cutting erosion and carbon loss. The need for specialised planting tools may limit the adoption of this practice by small landholders (IFAD 2011). Where machinery is used Global Positioning System (GPS) technology can be used to control traffic and minimise soil compaction (Box 12). Further initiatives for reducing water use and improving water quality are via wetland restoration, improving water efficiency through better irrigation and irrigation recycling pits; and efficient use of rainfall and stormwater management.

Box 12: Control traffic and conservation tillage – China

Research from China's dryland Loess Plateau found runoff from controlled traffic was 20% lower than from conventional tillage plots and soil erosion declined by 16% (Zhang 2002). Furthermore random field traffic was found to increase fuel consumption by 26-30% compared with controlled traffic practices (Li, Gao et al. 2000).

Box 13: Precision farming in Africa

The introduction of micro-dosing into Zimbabwe, Mozambique and South Africa is making fertiliser use a productive and economically viable option for the farmers. Barriers to the uptake of micro-dosing have included lack of access to fertiliser and credit, insufficient training and lack of supportive policies. In eastern and southern Africa, farmers are working with private fertiliser companies to identify appropriate fertiliser types and promote the sale of small packets suited to the resource constraints of small-scale farmers. It is hoped that the number of farmers using the micro-dosing techniques will increase in the next few years from 25,000 to 500,000. (ICRISAT 2009)

Precision agriculture ensures that water, fertiliser, animal waste, herbicides and pesticides are from the right source and applied at the right time, amount, place and manner. The level of precision agriculture can vary from increasing local capability (Box 13) through to sophisticated technology such as Remote Sensing (RS), GIS, GPS, Soil Testing, Yield Monitors and Variable Rate Technology. While the small size of many Asia farm's is an obstacle to the uptake of this technology, there may be business opportunities for precision farming technologies in many developing countries (Shanwad, Patil et al. 2004).

4.6 Access to markets

Beef production in Asia will continue to become more evolve market based. The role of small rural producers and traditional beef production, and the power relations among all the stakeholders in these developing and increasingly vertically integrated markets, is of the utmost concern. Access to these markets means producers can reliably sell more produce at higher prices. This means they can then risk investing in the technology and inputs required to produce better quality beef which adheres to tightening sanitary and phytosanitary regulations increasingly being required to participate in these markets. Advancement in telecommunications facilities in some countries has helped producers to get access to market information and knowledge on best practice farm practices (Box 14).

Box 14: Using IT to develop integrated supply chains and promote best practice production – India

The e-Choupal model has been designed to tackle the challenges of fragmented farms, weak infrastructure and the involvement of numerous intermediaries. Technology (via village internet kiosks) is used to virtually cluster all the value-chain participants, delivering the same benefits as vertically integrated chains does in mature agricultural economies. Producers can get access to weather and market prices, and knowledge on scientific farm practices and risk management. They can facilitate the sale of farm inputs and purchase farm produce at fair prices. e-Choupal was launched in 2000 and has become the largest initiative among all Internet-based interventions in rural India reaching over 4 million farmers. The project how plans to integrate bulk storage, handling and transportation facilities to improve logistics efficiencies.(ITC 2013)

5 GREENING IN SLAUGHTERING AND MEAT PROCESSING

5.1 Overview

Slaughterhouses in the Asian region can be generally split into three groups (APEDA 2008, Heinz 2008):

1) The first are the relatively modern, sometimes world class, well-equipped and hygienically operating abattoirs that produce for export or domestic quality meat markets (Figure 7). These include extensive processing of meat by-products.

2) The second consist of large, old abattoirs in major cities that are in need of repair and struggle with pollution problems, producing products which often do not meet hygienic standards or customer expectations or needs.

3) The third and largest group is composed of small and medium-sized private or municipal abattoirs. This group is variable in terms of availability and quality of equipment and slaughter hygiene, and also produce products that may not meet hygienic standards. Little or no formal by-product processing occurs within this group and there can be significant waste and pollution problems.

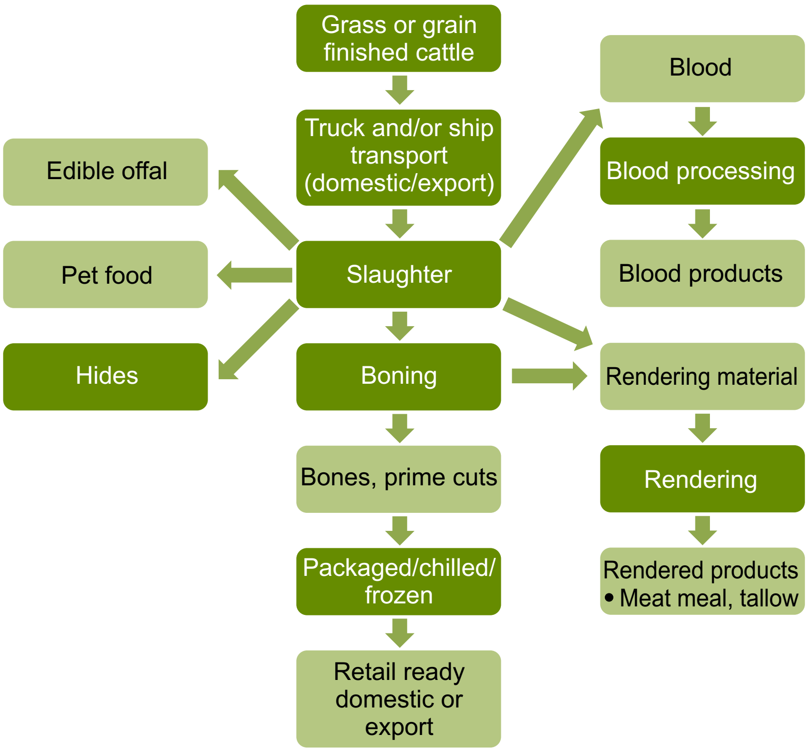

Figure 7: Slaughtering and meat processing with rendering and by-product production

For example, India has 44 government-registered, export-approved abattoirs (APEDA 2013). These have world class processing and sanitary procedures with the mandatory requirement for hazard analysis critical control point (HACCP) and ISO quality certification. There are around 4,000 locally registered slaughterhouses for the domestic market and around 25,000 unregistered premises (APEDA 2008).

The main stages of meat processing are shown in Table 3 (Pagan, Renouf et al. 2002, AMPC and MLA 2010). The majority of slaughterhouses across Asia have limited access to refrigeration and so the steps involving chilling, packaging and refrigeration would only be undertaken by export licensed and/or advanced processors. Aside from hide and skin processing, the list of additional meat processing activities would also generally only be undertaken by larger, more advanced processors which have the advantage of economies of scale. Wastewater treatment would also occur at varying degrees for different processors, ranging from simple primary treatment to advanced treatment technologies.

Table 3: Stages in meat processing

(Pagan, Renouf et al. 2002, AMPC and MLA 2010)

Main meat processing stages	Additional activities
Receiving and holding	Rendering
Preparation for slaughter (washing)	Hide and skin processing
Slaughter	Blood processing
Hide/skin removal	Water pre-treatment
Removal of internal organs (evisceration)	Paunch processing
Trimming and carcase washing	Wastewater treatment and discharge
Weighing and grading	
Chilling	
Boning	
Packaging	
Freezing or cold storage	
Plant cleaning	

Each of the stages shown has specific environmental impacts, challenges and related opportunities and these are discussed below. While it is difficult to make comparisons of resource use between facilities, it is good strategy to regularly monitor resource use within a facility to help gain an understanding of efficiencies and potentially highlight areas for improvement using procedures for cleaner production, waste minimisation and best practice resource use.

5.2 Energy use

Energy requirements for slaughterhouses vary depending on the scale of processing equipment and the extent of by-product processing. Advanced processing plants use significant amounts of electricity for refrigeration, air conditioning, lighting, pumps, motors and other equipment items. Thermal energy is used to produce steam and hot water. An indication of the breakdown of electrical and thermal energy use is shown in Figure 8.

Local, small-scale slaughterhouses in developing countries have less, if any, automated equipment and generally no refrigeration. Many of the steps around slaughter, hide removal, washing, trimming, boning and related procedures are carried out manually and so energy requirements are significantly less, however, human labour makes up for this.

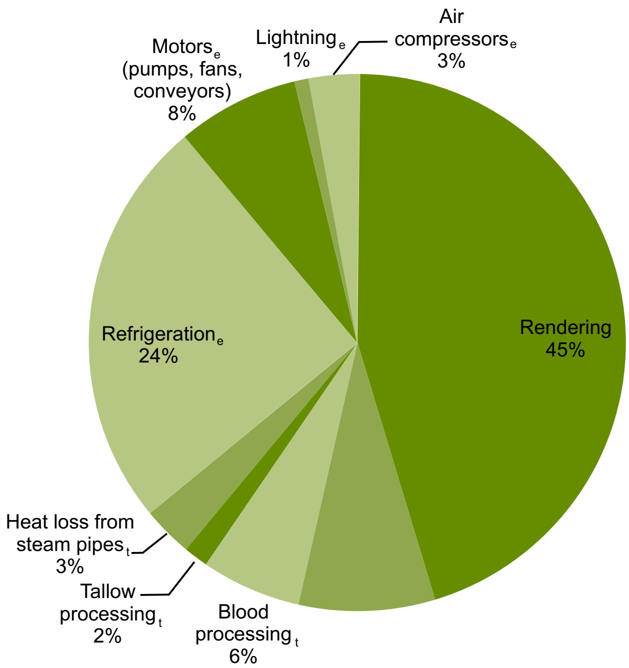

Figure 8: Breakdown of electrical$_e$ and thermal$_t$ energy use for an advanced meat processing with rendering

(Pagan, Renouf et al. 2002).

Table 4 lists potential energy saving opportunities for an advanced meat processing facility. These opportunities can be considered by less advanced processors when upgrading or installing new equipment, or when responding to government regulations, such as cleaner production, hygiene regulations or pollution abatement. A detailed energy assessment will highlight which of these opportunities are relevant to individual processors.

5.3 Greenhouse gas emissions

Greenhouse gas emissions from meat processing vary considerably, in particular due to the source of energy; the extent of energy-intensive by-product processing (rendering); edible offal processing; and the level of wastewater treatment.

Fossil fuels continue to be the most commonly used source of energy across Asia, with coal being the main source of fuel for electricity in China (65% of installed capacity) and India (57% of installed capacity) (US Energy Information Administration 2011). Biomass is a significant source of primary energy for some countries, contributing 23% of India's total energy supply and around 25% of Indonesia's total supply (US Energy Information Administration 2011, Hasan, Mahlia et al. 2012). Other renewable energy sources, such as solar, wind and geothermal, make up relatively small portions of energy supply across the continent and are acknowledged as requiring extensive government policy support (Hasan, Mahlia et al. 2012). A number of recent Australian studies specific to meat processing have concluded that renewable energy sources of solar PV, solar thermal, wind and geothermal are still economically unfeasible (Franklin, Jordan et al. 2010, Spence 2012). In the Asian context, the fact that there are very few clean development mechanism investment projects being carried out in Asia at present appears to support this conclusion.

Table 4: Energy-saving opportunities in meat processing
(Pagan, Renouf et al. 2002, MLA 2008)

Thermal energy
Boiler burner tuning
Flash steam recovery
Boiler drum total dissolved solids (TDS) level
Blowdown heat recovery
Boiler economiser
Cooker waste heat recovery
Increase condensate recovery
Sterilisers' waste heat recovery
Improve boiler part load performance
Reduce hot water use
Reduce heat loss from steam pipes
Refrigeration
Sub-metering (monitoring & targeting)
Reduce refrigeration lift
Review boning room fresh air intake
Use of plate freezers
Use of dehumidifiers in freezers
Automate refrigeration system control
Floating head condenser control
Evaporative/chilled water spray precooling
Variable speed drives on trim screw compressors
Other energy-saving opportunities
Sub-metering and monitoring
Eliminate compressed air leaks
VSD on screw air compressors
Optimise sequencing of air compressors
Demand-side management
Power factor correction
Purchase energy-efficient motors
Improve lighting control and energ- efficient lighting (LED)
Biogas capture and use

Box 15: Assessment of algae, PV and wind for a meat processor
(Spence 2012)

An assessment of three renewable energy sources (algae for biodiesel production, solar photovoltaics and wind) was undertaken for an Australian meat processor. They were found to be not cost-effective at existing electricity prices. However, the use of solar thermal energy to dry paunch was a promising way to produce useful biomass to replace boiler coal for water heating and for pyrolysis to generate electricity.

Meat processors can supplement conventional fuel oil sources with tallow or biogas (discussed below). However, the combustion of these various fuel types may require significant investment e.g. for dual or multi-fuel boiler systems, as well as another layer of expertise in running the plant effectively. An Australian study also indicated promising results in solar drying of paunch for use as an alternative boiler fuel and for pyrolysis for electricity generation (Spence 2012) (Box 15).

Biogas capture and use – The biogas from anaerobic wastewater treatment plants in red meat processing can comprise up to 60-70% methane for an effectively operating system and this can be responsible for up to 50-60% of the sites' overall GHG emissions (White, Johns et al. 2013). With a global warming potential 21-23 times higher than carbon dioxide, the methane should be captured and used to supplement fuel supplies or otherwise flared to reduce GHG emissions. There is also potential for the gas to be used in a fuel cell for electricity generation (Franklin, Jordan et al. 2010). For small-scale meat processing plants, there is potential to capture biogas from paunch and yard manure and use the resulting fuel to reduce traditional fossil fuel-based energy sources (Franklin, Jordan et al. 2010, Nepal Biomass Support Program 2012). Alternately, the manure could be dried and combusted directly (Heinz 2008) describes an anaerobic digester specifically for small to medium-sized abattoirs, discussed further below.

5.4 Water and wastewater

Treated, potable water is an essential resource in all food processing and directly contributes to the ability to produce a safe hygienic product. In meat production, hygiene is of utmost importance and thus a safe, reliable supply of high-quality water is a prerequisite.

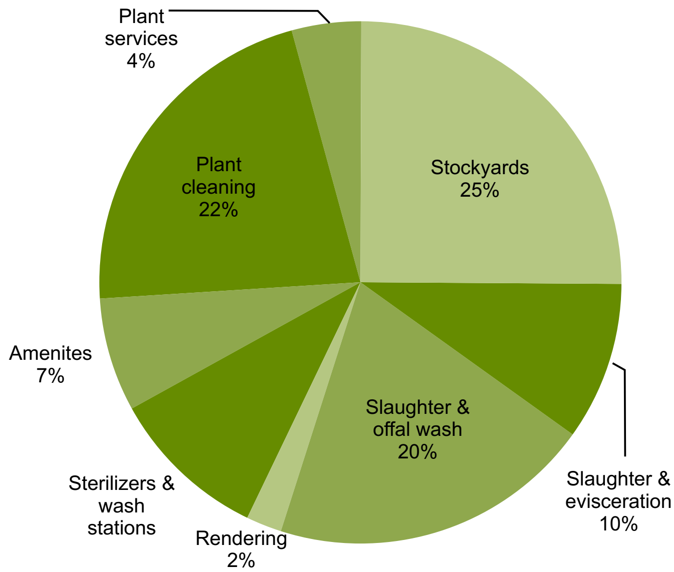

Figure 9: Breakdown of water use for an advances meat processor with rendering

(Pagan, Renouf et al. 2002).

In all meat processing, most water is used in cleaning and sanitising, regardless of whether it is an export grade facility or a small slaughterhouse producing meat product for the local market. Of course, there are vast differences in the quantity of water consumed. Figure 9 gives an example of the water use for a typical export grade meat processing plant. The best option in reducing water use and the need for wastewater treatment is to minimise the amount of water used to begin with. A list of opportunities for slaughterhouses is shown in Table 5. Using water-efficient equipment items, including spray nozzles, timers, automatic control switches, efficient wash systems, along with good housekeeping procedures such as repairing of water and steam leaks, will go a long way to reducing water use and wastewater generation. It should be noted that savings in heating water and producing steam will have a dual saving effect in reducing energy. For small and medium-sized slaughterhouses, dry cleaning and selection of "cleaning friendly" smooth, washable and impermeable surfaces, as opposed to concrete floors, can help reduce water use (Heinz 2008). Good design will also help maximise blood collection and prevent blood from entering wastewater streams as far as possible (AMPC and MLA 2003). Further information can be found in the *Eco-Efficiency Manual for Red Meat Processing* (Pagan, Renouf et al. 2002).

There are a variety of wastewater treatment options for advanced processors covering the gamut of primary, secondary and tertiary treatment options (Pagan, Renouf et al. 2002, AMPC and MLA 2010). However, these are often beyond the reach of most small and medium-sized abattoirs in Asia. Simple settling pits and septic tanks cannot treat abattoir wastewater effectively. The pollution issues are vast, with numerous examples of blood and wastewater discharged into open drains and flowing to nearby waterways, often in settled urban or village areas. One viable treatment method is biogas digestion (Heinz 2008). It should be noted that biogas digesters used for farm purposes need to be modified for abattoirs because the effluents from these facilities contain higher loads of fat residues. A number of Asian countries, including India, Nepal, Pakistan and Philippines, have support programmes run by government or NGOs to assist abattoirs to install treatment facilities (Van Ness 2006). In an example of industrial ecology, one review positively assesses the feasibility of collection of slaughterhouse and other food processing wastes for biogas production to supplement power supplies for the city of Haridwar, India (Siddharth and Sharma 2011). Operational para-meters and costs for biogas production in India are described by the Centre for Environment and Development (46).

Table 5: Water-saving opportunities in meat processing

(Pagan, Renouf et al. 2002, Heinz 2008)

Less advanced processors
Monitoring and target setting for site water use
Fitting efficient spray nozzles
Reducing diameter of delivery lines
Repair all leaks
Install smooth, cleanable surfaces to reduce wash water
Design of slaughter blocks to maximise blood collection and for clean-ability
On/off switches to prevent waste
Intermittent flows on table wash sprays
Water efficient fittings for casings and offal wash
Dry rather than wet paunch disposal
Dry cleaning as far as possible before wet
Timer controls on hand wash basins
Advanced meat processors
Monitoring and target setting for water use
Centralised control of water supplies
Avoid under-utilisation of sprays for stock wash
Intermittent flow for viscera table wash sprays
Flow control on continuous flow sterilisers
Sensor control on automatic carcase washing
Water sprays on splitting saws to reduce bone dust and carcasse washing
On/off control for cooling water on breaking saws
Automatic controls for hand washing
High pressure water ring main for cleaning
Recycling of cooling tower water

5.5 Solid waste management and by-product usage

A variety of by-products are produced in beef processing as shown in Figure 10. When all possible by-products are fully used, it has been found they can generate around 11% of the gross income (Liu 2011). However, not all supply chains are developed in a way that makes this possible. For example, blood is an extremely valuable co-product of meat processing and can be valued in the order of US$900/ton for dried blood and blood meal, and US$1,000/kg for pharmaceutical grade value-added products (AMPC and MLA 2003, Veal 2008, Levonian 2013). Turning blood into a hygienic product requires advanced processing and access to refrigeration. But for small and medium-sized processors, the relatively low quantity of by-products, along with their location, can make it financially unviable to undertake advanced processing (Indian CED 2011). The fact that some meat products, such as brain and spinal cord, are banned from human consumption due to the outbreak of “mad cow” disease (Liu 2011) also limits producers' options.

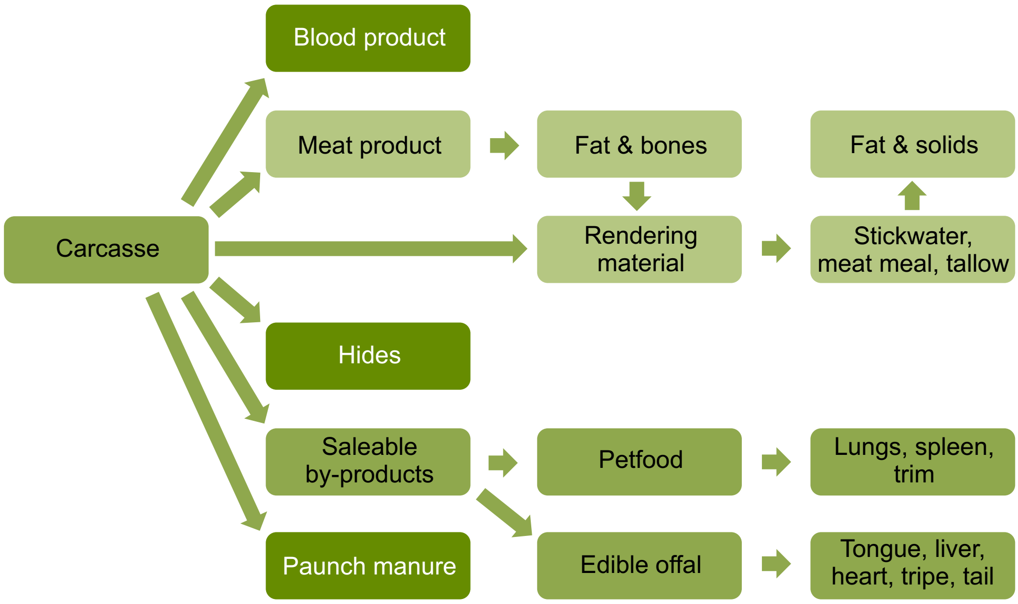

Figure 10: By-products in red meat processing

Meat by-products generally have a high nutrient value. Where supply chains are not developed to take full advantage of by-products, it is important they are managed in a way that minimises environmental impacts. Dry cleaning and collection should be undertaken as far as possible to minimise nutrient loads on wastewater, e.g. blood, fat, paunch manure and trimmings should be collected for treatment and disposal in the solid waste stream.

Table 6: Options for solid waste disposal of red meat processing by-products

(Adapted from (AMPC and MLA 2010))

Disposal method	Suitable for	Comments
Less advanced processors		
Composting	All organic solids	Product can be used as soil conditioner. Odour is an issue. Consider soil nutrient requirements
Dry composting	Blood, dead animals, slaughter & boning wastes, biogas residue	Need to cover to protect from elements and scavengers. Consider soil nutrient requirements
Vermi-composting	Blood, manure, paunch contents, aerobic treatment sludge	Requires significant investment and management. Variable success
Surface spreading	Blood, paunch contents, manure, anaerobic pond sludge, biogas residue	Odour and hygiene issues. Should be incorporated into soil soon after spreading. Consider soil nutrient requirements. In decline in Europe
Sub-surface injection	Paunch contents, DAF sludge, Aerobic treatment sludge, biogas residue	Reduces fly problems. Impact on soil must be monitored and nutrient requirements
Burning/incineration	Dead animals, slaughter and bone wastes	Loss of opportunity of nutrient recovery. High temperature incineration is preferred
Advanced processors		
Anaerobic lagoons	Paunch contents Aerobic treatment sludge	
Anaerobic digestion - continuous stirred reactor	Paunch contents, manure	Biogas is produced for flaring or fuel. Solids are applied to land
Rendering	Bones, fat, trims, Primary effluent screenings	Market affected by outbreak of disease e.g. bovine spongiform encephalopathy
Alkaline hydrolysis	Blood, dead animals, slaughter and boning wastes	Relatively new technology shown to be capable of inactivating pathogens

Potential methods of solid waste treatment and disposal are outlined in Table 6. Those methods most accessible to less advanced processors are composting, surface spreading and sub-surface injection methods. There can be health and hygiene implications if these disposal methods are not properly managed (Ingrid and Heribert 2012). For advanced processors, rendering has been the main form of solid waste management, however, in Europe, recent outbreaks of disease have damaged the market for rendered products and other forms of waste management are being investigated, such as alkaline hydrolysis (Ingrid and Heribert 2012). In India, the recommended methods of slaughterhouse wastes disposal are composting, biogas production and rendering (Indian CED 2011). Incineration can also be an option. Trials have also indicated that pyrolysis, gasification and combustion are technically viable for the processing of abattoir solid wastes, particularly paunch waste and DAF sludge (Bridle 2011, Spence 2012).

Generally, all forms of solid waste treatment presented have benefits in:

- indirectly reducing greenhouse gas emissions;
- providing an alternate energy source (biogas or paunch);
- preventing nutrient-rich wastes from entering waste streams; and
- promoting recycling of nutrient resources which are a less energy-intensive alternative to conventional fertilisers (Arthurson 2009).

The efficient production of compost requires close monitoring and management. The use of aerated piles as opposed to windrows has been shown to reduce overall carbon emissions (Box 16). Abattoir waste and fresh manure are high in nutrients, moisture and bulk density and need to be mixed with other wastes (bulking agents) that have a high carbon content to provide a balanced mix. Example bulking agents are wheat straw, bark, grass clippings or sawdust (Australian Meat Processing Corporation (AMPC) and Meat and Livestock Australia (MLA) 2002)

Box 16: GHG emissions from compost of paunch
(Australian Department of Agriculture Fisheries and Forestry 2012)

An Australian trial utilised paunch from two abattoirs, which was either stockpiled or blended with shredded vegetation residues and then composted in small turned windrows or aerated piles for eight weeks, followed by a three week maturation phase.

Use of aerated piles rather than turned windrows for composting reduced methane and nitrous oxide emissions by 62% and produced the least GHG emissions overall when including CO_2. The study highlighted the need for good compost management procedures for best results.

5.6 Chemical use

Chemicals are used in meat processing for cleaning and sanitising of operating equipment and surroundings. Table 7 shows the typical chemicals used and their purpose. Opportunities for reducing chemical usage include:

- undertaking dry cleaning as far as possible;
- review and rationalising use of cleaning and sanitising agents;
- use of automatic dosing systems and clean-in-place (CIP); and
- use of environmentally friendly cleaning agents (Pagan, Renouf et al. 2002).

Table 7: Cleaning and sanitising chemicals used in meat processing

(Pagan, Prasad et al. 2004, CSIRO 2011, ChemStation 2013)

Type of chemical/agent	Application	Function
Cleaning agents		
Multi-purpose	Easy to remove soil	Manual, pressure and foam cleaning all surfaces
Alkaline	Fats, protein, organic soil	Clean-in-place and soak tank. Breaking down fats to suspend in solution. Breaking down fats to form soaps. Forming colloidal solutions
Acidic	Protein, metal corrosion	Mineral deposit control. Water softening
Enzyme assisted	Protein, fats, oils	Used in conjunction with mild detergents to break down and solubilise difficult to remove soils
Complex phosphates	Fats, proteins	Soil displacement. Dispersion of soil. Water softening. Prevention of soil re-deposition
Disinfectants		**Comments**
Chlorine compounds	Wide ranging	Kills broad spectrum of microorganisms. Corrosive
Quaternary ammonium compounds (QUATS)	Effective in acidic environment. Affected by water hardness.	Stable, long shelf life, less corrosive. Leaves residues, high foaming e.g. in CIP
Acid-anionic combinations	Slightly corrosive and irritating. Not effective at alkaline pH	Less corrosive than chlorine. Narrow spectrum of anti-microbial activity
Iodine-based compounds	Wide-ranging	Stable, long shelf life, less corrosive. Can stain. Less effective against bacterial spores than chlorine
Peroxyacetic acid	Wide ranging Effective at pH less than 7–8	Biodegradable. Concentrated form hazardous, irritant and corrosive
Ozone	Meat packing and wastewater treatment	
Alcohol	Neutral to slightly acidic	Fast acting, Not effective against spores, limited effectiveness against viruses, flammable

5.7 Environmental impacts of value-added meat processing

Value-added meat processing is common throughout Asia with the production of tinned meats, mince, burgers, sausages, fermented and dried meats and other products. Small-scale meat processing provides the option to manufacture products with increased shelf life, e.g. through drying or other preserving measures such as salting, smoking, fermentation or heat treatment. This enables communities to cater for periods when meat might not be available (Heinz and Hautzinger 2007).

Larger scale meat processing plants have the opportunity to capitalise on the increasing demand for meat products. A comprehensive guide to value-added meat processing is provided by Heinz and Hautzinger (Heinz and Hautzinger 2007). There are relatively fewer environmental impacts of value-added meat processing compared with upstream meat processing, particularly in relation to the generation of solid and liquid wastes, although it can still be polluting. Depending on the scale of operation, biogas digestion and composting could potentially be used to treat these types of wastes, as described for general meat processing. However, where there is minimal option for treatment, these wastes are more likely to be disposed relatively untreated to sewers or other general waste streams. Resource efficiency opportunities (water and energy savings) are similar to those described for general meat processing.

5.8 Packaging

Packaging is an important part of meat processing, employed mainly to protect the product from contamination (dirt, microbes, and vermin) and damage during processing, storage and distribution. It is also used to attract a higher number of consumers. Types of packaging used in meat processing are shown in Table 9. Though some materials can be recycled, this may not always be possible for logistical, financial, or hygienic reasons.

Table 8: Reducing impacts of packaging

(Pagan, Prasad et al. 2004)

Avoid unnecessary packaging
Eliminate unnecessary packaging via design
Order bulk delivery of products e.g. chemicals, food additives
Review handling and distribution measures e.g. clean-in-place systems, conveyors for bulk
Reduce packaging
Light-weighting of packaging
Minimise use of adhesives e.g. tapes, glues
Optimise packing lines e.g. canning, box construction, vacuum packing to minimise waste
Optimise receiving, handling and storage to prevent contamination and/or damage
Reuse packaging
Return to supplier for re-use e.g. drums, cartons, plastic containers
Reuse within the plant operation
Pass to third party for reuse
Avoid damage to promote reuse
Recycle packaging
Separate recyclable waste
Adopt purchase policy that includes recyclables
Use bio-degradable packaging
Disposal
Dispose in a manner that minimises environmental impact

Table 9: Packaging used in meat processing

(Pagan, Prasad et al. 2004)

Use	Type	Recycle potential
Cans	Aluminium, tin, steel	commonly recycled
Boxes	Cardboard Virgin or recycled compostable, combustible Non-coated or coated Single or corrugated Combined with plastic or foil — liquid-proof	commonly recycled
Meat trays	Polystyrene — expandable	difficult
Flexible wraps	Cellophane (regenerated cellulose)	difficult
Bags	Poly-vinyl chloride (PVC) Polypropylene Polyethylene Aluminium foil Poly-amide	difficult
Boil-in-a-bag		difficult

6 GREENING IN TANNING AND LEATHER PROCESSING

6.1 Overview of process

Animal hides may be thought of as a waste product, a by-product or indeed the final product in some instances, depending on the relative value of the skin and the amount of processing required. The aim of tanning is to optimise the usefulness and value of the hide, whilst the aim of the animal production process should be to optimise all valuable parts of the animal ensuring the skin is in its best possible condition, not affected by horn or other injury, and is not damaged during storage and transport.

Tanning is the process of treating raw animal skins to make them stronger, more flexible and resistant to decay. The process involves exposing the skins to a number of treatments resulting in generation of potentially polluting waste streams which must be appropriately managed. Trade in leather and leather products is one of the largest markets in the world. It is worth around US$80 billion per year (International Trade Centre n.d.), with developing and emerging economies replacing developed countries as the largest suppliers of leather (Joseph and Nithya 2009). The world leather industry processes approximately 15 million tons of hides and skins per year and discharges approximately 15,000 megalitres of wastewater per day (Rajamani, Chen et al. 2009). World solid waste production for tanneries has been estimated at 6 million tons/yr along with approximately 4.5 million tons/yr of sludge from effluent treatment plants (Rajamani, Chen et al. 2009).

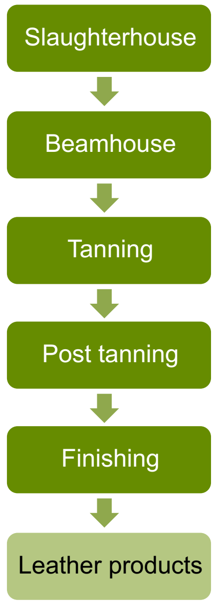

Figure 11: Leather processing

There are four main steps in leather treatment: Pre-tanning or "beamhouse", tanning, post-tanning and finishing (Figure 11). Beamhouse operations include processes such as preserving then removing unwanted components, e.g. salt, flesh, hair and grease, trimming, treating and stretching. The tanning process involves soaking the hides, traditionally in a chromium salt solution to prevent decomposition. The post-tanning process can include retanning, treatment with dye and fat before drying, splitting and shaving. The finishing process provides the final qualities of the leather by processes such as conditioning, buffering and trimming. Transport from the slaughterhouse to tanneries and of the final product to further processing or to consumers could also be considered as further steps in the process.

The major environmental impacts in leather processing occur during the tanning process itself and in the disposal of residual solid wastes. Distribution, retail and end-of-life disposal environmental impacts have been found to be less significant (Cleaner Production Institute 2009). Approximately only 20% of all raw material used in leather production ends up in the finished product, with the remainder becoming solid or liquid waste (Huffer and Taeger 2004) (Cleaner Production Institute 2009). Approximately 90% of the wastewater pollution from the leather industry is associated with the "wet blue" process, which converts raw hides and skins to tanned leather using chromium salts (Blackman and Kildegaard 2010). The majority of contaminates are produced during stages of dehairing, which involves soaking in lime and sodium sulphide; and chrome tanning.

The main environmental impacts that can result from the tanning process include:

- wastewater streams with high biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) and chemicals such as chromium and sulphur dioxide;
- high water and energy use;
- air emissions including CO_2e from fuel and electricity use, and odorous chemicals such as mercaptans (sulphur-containing organic compound) and sulphur dioxide; and
- solid wastes including hair, fat and other biodegradable waste such as wastewater treatment sludge containing heavy metals.

There is also potential for occupational health and safety problems occurring from factors such as mismanagement of chemicals, harmful working conditions and lack of training.

A well-managed tannery where resource use is minimised and all waste streams are properly treated has a limited impact on the environment whilst producing a product that has many uses.

6.2 Improved efficiency and greening opportunities

Methods to improve efficiency start on the farm to reduce damage to the skins during rearing and slaughtering. This reduces waste skins and the need to use masking chemicals to hide damage (IUE 2008).

The environmental impact particularly of the tanning and finishing process can be reduced through the elimination of environmentally unsound chemicals such as dyestuff, heavy metals and other restricted products. Many companies apply their own list of restricted substances in leather. However, leather manufactured in or imported into the EU must comply with the REACH Regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals) which aims to protect human health and the environment from the potential risks of chemical use (European Commission 2013). This regulation provides a framework for chemicals that should be restricted in leather products and should be considered as the basis for development of a list of restricted substances in leather production.

Box 17: PrimeAsia Leather Co. Viet Nam reduces water consumption by 46%
(The Leather Working Group n.d.)

PrimeAsia Leather Co. in Viet Nam have improved water recycling practices reducing water consumption from 125.6L/m2 of leather to 67.7 L/m2 of leather: a reduction of 46%.

Water-saving initiatives include rainwater collection for use in wetback drum, recycling of wetback drum water, recycled water for water wash spray machines and for machine cleaning.

Strict control and measurement can reduce water use by 30% or more (IUE 2008). Recycling float for processes can reduce water consumption by 20-40%, reduce chemical use by up to 50% and reduce wastewater contaminants by up to 30% (IUE 2008). Biological treatment of effluent on-site can allow substitution of fresh water with treated effluent.

Due to the cost and specialisation of wastewater treatment and other cleaner production initiatives required for tanneries, there is often a cost and environmental benefit of setting up industrial zones or clusters of tanneries with common effluent treatment plants and access to specialised environmental services. Countries such as China, India and Turkey have started to relocate tanneries from urban areas to specific industrial zones (Rajamani, Chen et al. 2009). Similarly, ensuring a senior staff member is properly trained and competent in handling environmental issues, and in particular wastewater treatment, would also reduce environmental impacts of the tannery (UNIDO 2011).

Methods to improve efficiency and cleaner methods of tanning are provided in Table 10.

Table 10: Green tanning options

Greening Method	Comments	Basis of the initiative			Further information
		More efficient use of chemicals	New chemicals or processes	New equipment	
Improve farming practices through a QA or clean hide scheme	Reduced parasite infestation and hide damage from external sources such as barbed wire. Reduce dried dung on hides. Eliminates additional processes required to mask damage	✓	✓		(IUE 2008)
Work with slaughterhouse	Reduced damage to skins during skinning. Reduces waste and masking.		✓		(IUE 2008)
Mechanical skinning	Reduces damage to hides but not always feasible for smaller abattoirs.			✓	(Ingle, Harada et al. 2011)
Transport					
Locate tannery near abattoir and use of refrigeration	Reduce need for preservatives by 3 weeks. Eliminate salt preservation phase and reduce wastewater. Only works where tannery can be located near to abattoirs. Unfeasible option where global trade in skins occur.	✓	✓	✓	(IUE 2008)
Use of fungicide to prevent mould during transport	Prevent discoloration. Can only use approved and not restricted substances.	✓	✓	✓	(BMT Surveys n.d.)
Preservation of rawstock					
Shade drying	Eliminated salt preservation phase & reduced wastewater. Low cost. Only works in some climates	✓			(IUE 2008)
Air drying and salt curing	Reduced salt use	✓			(IUE 2008)
Antibiotic use to increase storage time	Eliminated salt preservation phase and reduced wastewater	✓	✓		(Ludvik 2000)
Short-term preservation - cooling	Salt reduction/easier soaking	✓			(Ludvik 2000)
Partial salt elimination	Up to 10% salt reduction	✓			(Ludvik 2000)
Beamhouse					
Counter current soaking	Concentration of salt, blood and other debris in the first tank.		✓	✓	(IUE 2008)
Green fleshing after soaking	Allows better tallow recovery than from lime soaked fleshing	✓	✓		(IUE 2008)
Hair recovery before dissolution.	Reduce COD by 15-20% and TN by 25-30% in effluent stream	✓	✓	✓	(Frendrup 2000, Ludvik 2000)
Direct recycling of liming float	Up to 40% saving in sodium sulphide, up to 50% saving in lime; 30-40% decrease in COD and 35% decrease in nitrogen in effluent mix.	✓		✓	(Ludvik 2000)
Splitting lime	Reduces chromium use and produces by-product for food casings or gelatine production	✓	✓		(Ludvik 2000)
CO_2 delimine to replace ammonium salts	Reduces ammoniacal nitrogen production	✓	✓		(Ludvik 2000)
Tanning					
Recycling pickling floats	Save up to 80% normal salts used and 20-25% pickling acid.	✓	✓		(Ludvik 2000)
Recovery of solvent degreasing agent	Recovery of natural grease for commercial use	✓			(IUE 2008)
Using non-solvent methods	Eliminates solvents.	✓	✓		(IUE 2008)
Wet-white pre-tanning	Reduces tanned waste				(Ludvik 2000)
Improved chrome tanning	Improved efficiency of tanning, process control, drums modification	✓			(Ludvik 2000, IUE 2008)
Direct recycling of chromium tanning floats	Reduction in 20% of chromium and salts	✓	✓		(Ludvik 2000, IUE 2008)
Recovery of chromium after precipitation	For large quantities of chromium bearing floats.	✓	✓		(Ludvik 2000)
High-exhaustion chromium salts, adapted basification products and/or temperature increases	Reduced chromium concentrations.	✓	✓		(Ludvik 2000)
Chromium free tanning	Refer to Table 11	✓	✓	✓	Table 11
Post-tanning operations					
Eliminate environmentally unsound dyestuff	For example those containing benzidine and other banned aromatic amines		✓		(Ludvik 2000)
Eliminate halogenated oils in fat liquors		✓	✓		(Ludvik 2000)
Finishing operations					
Use water-based finishes	Available for spray dyeing	✓	✓	✓	(Ludvik 2000)
Eliminate heavy metals & other restricted products		✓	✓		(Ludvik 2000)
Roller or curtain coating machines preferable	Cannot be used for all leather types	✓	✓	✓	(Ludvik 2000, IUE 2008)
Spray units with econo-misers and high-volume, low-pressure spray guns	Reduced discharges to environment	✓	✓	✓	(Ludvik 2000)

6.3 Alternative tanning methods

The two traditional tanning methods are the slow vegetable method and the preferred chrome tanning method. However, more recently other tanning methods such as organic aldehyde and semi-metal tanning methods are becoming more prevalent as they reduce the chrome content while producing a more stable leather than is possible by using vegetable methods. When choosing tanning methods, the properties of the finished leather need to be considered as each method produces a slightly different product. Full life-cycle assessments of each tanning process should be undertaken to weigh up its relative advantages and disadvantages, including the economics of each process. Some of the advantages and disadvantages of each method are provided in Table 11.

Table 11: Alternative tanning methods

Tanning method	Description	Advantages	Disadvantages
Vegetable	Use of natural tannins	Environmentally friendly Minimises waste Vegetable tanning floats can be recovered by ultrafiltration.	Slow process Lower grade leather (Blackman and Kildegaard 2010) High pollution load Slow biodegradability (Krishnamoorthy, Sadulla et al. 2012) Low shrinkage temperature of the finished product (Musa, Madhan et al. 2010)
Chrome	Uses a mixture of salts and chromium solution	Used for approx. 80-90% of worldwide tanning. Fast, stable, well known, accepted	Needs care in disposal Untreated wastewater stream highly contaminating.
Titanium/ Chrome	Uses titanium to reduce chrome use.	Higher chrome uptake therefore less chrome in the wastewater stream (Sivakumar, Jeyaraj et al. 2008) Strength and other functional properties of the produce similar to chrome tanning	Chrome in wastewater discharge.
Organic/ Aldehyde tanning	Use of organic tanning agents using polymers or condensed plant polyphenols with aldehydic crosslinks	Mineral free leather High hydrothermal stability of chrome leather (Krishnamoorthy, Sadulla et al. 2012)	More filled and hydrophilic than chromium leather
Semi-metal	Using metal salt such as Al (III) with a plant polyphenol to produce chrome-free leather	High hydrothermal stability of end product	Aluminium in wastewater stream needs to be treated.

6.4 Effluent treatment

In developing regions, tannery wastewater is often discharged untreated into waterways or into municipal sewage treatment plants. In some areas water quality discharge requirements exist but are not enforced (Blackman and Kildegaard 2010). In these areas private-sector trade associations can provide a better platform for clean technology information dissemination and improved results (Blackman and Kildegaard 2010).

Segregation of wastewater streams from Beamhouse, tanyard and finishing process is important as each stream has different concentrations of pollutants and should be treated separately (FAO 2011, UNIDO 2011). Multi-stage approaches to treat effluent should be taken depending on the production capacity, water consumption and wastewater generation, individual pollutant loads in the wastewater stream and requirements of the discharge stream.

Box 18: Salt recovery and reuse
(Pittards 2013)

Pittards Ethiopian Tannery S.C shakes hides and skins prior to processing to remove salts contaminated with blood, hair and other impurities. The salts are dissolved in water with the impurities settled out. Solar evaporation is then used to remove the water from the salt producing pure salt that can be reused. (Pittards 2013)

Where possible, tanneries developed or relocated in clusters or industrial zones can spread the cost of effluent treatment through the use of a common effluent treatment plant (CETP) (Rajamani, Chen et al. 2009). Effluent discharged into these CETP still requires pre-treatment to remove large particles, oils and grease and reduce chromium and sulphides before release (UNIDO 2011).

6.5 Waste management

Solid waste disposal is one of the major environmental issues facing tanneries. Potential reuse and disposal options for tannery waste streams are provided in Table 12.

The use of cleaner production methods outlined above can help reduce damaged rawstock and wasted leather and reduce the production of wastewater sludge. Geometricising rawstock (trimming the shape of untreated hides) before tanning can reduce the contamination of the offcuts (Centre Technique Cuir chaussure Maroquinerie 2000) as well as increase yield.

Table 12: Disposal options for tannery solid waste streams

(Puentener 2004, Özgünay, Çolak et al. 2007, Ingle, Harada et al. 2011)

Untanned fractions	Animal feed	Commodities	Fertilizer	Energy
Trimming	✓	✓	✓	✓
Hair		✓	✓	
Splits	✓	✓	✓	✓
Fleshings	✓	✓	✓	✓
Tanning fractions				
WB Trimmings		✓		
Splits		✓		
Shavings		✓		
Dyed trimmings		✓		
Effluent treatment				
Sludge		✓	✓	✓

Solid waste produced in the pre-tanning and slaughterhouse processes can be reused for products such as fish and poultry food, fertilisers and biodiesel (Ingle, Harada et al. 2011) and (Özgünay, Çolak et al. 2007). In countries such as Japan, metal-containing sludge is treated to generate by-products for use in the construction industry such as bricks (Ingle, Harada et al. 2011). Waste sludge can also be treated to obtain biogas. Chrome-free leather wastes and shavings can be composted to form slow nitrogen releasing fertiliser (Puentener 2004).

6.6 Energy management

The main uses of energy in leather production are in drying, in the production of hot water, steam generation and losses, operating motors, compressors and lighting. Energy reduction can be achieved through simple housekeeping measures and replacement of inefficient equipment, including actions such as:

- Improved management of the steam system, including insulating pipes, checking for leaks, steam condensate collection and reuse systems.
- Improved management of hot water systems, including insulation, hot water collection tanks and recirculation systems.
- Monitoring of gas, steam, temperature and other process parameters.
- Replacing or retrofitting inefficient hang drying chambers, motors and lighting.
- Improved management of compressed air systems, particularly in relation to air leaks (Cleaner Production Institute 2009, Joseph and Nithya 2009).

7 GREENING IN DISTRIBUTION

7.1 Transport

Demand for freight transport in Asia and the Pacific rose by 84% between 1995 and 2008 (UN 2011). With this rapid demand growth set to continue, Asia is expected to account for 31% of total worldwide transport-sector related CO_2 emissions by 2030 (ADB 2012), Efficient transport (road, rail and shipping) and storage facilities enable beef producers to not only access markets but also meet hygiene requirements. While they can typically achieve higher productivity with lower capital intensities than larger farms, this advantage can be lost as a result of post-harvest losses due to poor storage and transport facilities and high transport costs (Donnges, Edmonds et al. 2007). At the same time, access to overseas livestock and frozen beef is being facilitated by the fact that almost half the world's population lives within coastal zones, including 60% of China's population. Many Asian countries have chosen to invest first in modernising port facilities in or near large coastal urban areas for this reason (Armbruster and Coyle 2004). The distribution steps considered in this report are shown in Figure 12.

With respect to greening opportunities, the reduction of greenhouse gas emissions is perhaps the most important aspect and is discussed in more detail below. Some consideration should be given to reducing water use e.g. recycling and use of water efficient equipment for cleaning; and also solid wastes such as recycling of oil, batteries, tires, antifreeze, metal and plastic containers.

Box 19: Nitrogen-fuelled refrigeration units – UK (Ricklefs and Xhunga 2010)

ASDA (one of the UK's largest supermarket chains) is replacing its entire fleet of diesel-fuelled fridge units with liquid nitrogen units. The nitrogen is separated from air and produces zero CO_2 emissions (25 - 30 tons of CO_2 emitted by a diesel-fuelled refrigerated truck). Its minimal temperature variance is between 0.1°C and 0.7°C which reduces food spoilage, (diesel system's vary by up to 3.3°C). It retails for 10% more than diesel-fuelled refrigerated systems. When estimating the overall energy consumption from extraction to consumption, liquid nitrogen systems reduce carbon emissions by a factor of 4 (Commercial Transport Publishing Ltd 2011).

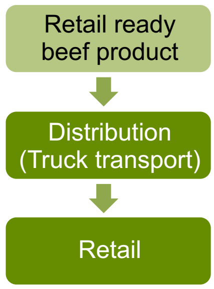

Figure 12: Beef production distribution

Energy and GHG emission

Opportunities for reducing greenhouse gas emissions in transport can result from using low carbon fuels and improving the efficiency of transports systems.

Alternate fuels

Asian bio-fuel blends accounted for 12% of global biodiesel production in 2010, the majority from first generation biofuels such as palm oil in Indonesia and Thailand (Larson 2008). While first-generation biofuels produce less greenhouse gas emissions than fossil fuels, there are serious issues with competition with food and livestock feed sources. Policy encouraging the use of second-generation biofuels, i.e. those which do not compete with food crops, is being widely adopted. China is set to become a world leader in the production of second-generation biofuels as part of its plan to reduce CO_2 emissions by 40-45% by 2020. India's biofuels policy also recommends that biodiesel be produced only from non-edible oil seeds, such as jatropha, that can grow in arid marginal lands

(Chand, Kumar et al. 2007). Beef producers are well positioned to use by-products of biofuels production for feed as a substitute for the higher priced crops used in feeding animals. In many cases, bio-fuel by-products represent an important component of bio-fuel industry revenues.

Transport efficiency

There are numerous means of improving the energy efficiency and carbon emissions of transport. For this report, only road transport has been considered (Table 13).

Table 13: Road transport initiative

(ADRET 2012)

	Fuel reduction (%)
Vehicle modification	
Alternative fuels e.g. CNG, LPG, hydrogen, hybrid electric	
Hybrid powertrain technology which harnesses the kinetic energy of breaking	25-50
Automated manual transmission to ensure optimum gear shifting	
Reduced rolling resistance tyres	1-13
Automatic tyre monitoring/inflation systems	2-4
Idle-management technologies with potential	5-8
Improved aerodynamics and drag reduction	3-25
Light weight trailers using aluminium, metal alloys, metal composites and other	5-10 per 10% weight decrease
Longer combination vehicles (multiple trailers or double stacking).	
Low-friction engine lubricants	3-5
More efficient and innovative refrigeration e.g. liquid nitrogen technology	
Efficient equipment and ancillary systems e.g. high-intensity discharge lamps (HIDs) and light-emitting diodes (LEDs), efficient alternators, power steering	
Driver practices and logistics	
Improved driver practices	14-20
Regular preventative maintenance	Up to 5
Improved logistics (strategic route practices)	

8 GREENING IN RETAIL AND CONSUMPTION

As discussed in section 3.5 (LCA waste), consumers in developed countries generate the greatest overall percentage of meat waste across the supply chain, at around 30-40% (Gustavsson, Cederberg et al. 2011). In developing countries, including South and Southeast Asia, the greatest percentage of losses are across the production, slaughter, processing and distribution stages due to less advanced supply chains with limitations in production, processing, cold storage, and transport infrastructure. But as supply chains in developing countries become more advanced, and demand increases, the level of consumer-generated waste is likely to rise to levels seen in developed countries. This high level of waste comprises significant amounts of embodied energy and water in the final product. The adoption of efficiently operated cold storage, coupled with consumer education, is therefore a key intervention point. The retail and consumption steps considered in this report are shown in Figure 13.

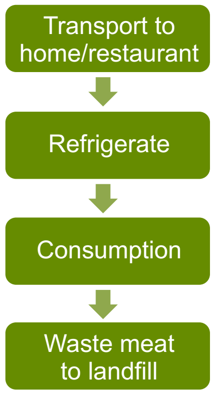

Figure 13: Retail purchase and consumption

8.1 Energy

Refrigeration is the most significant user of energy in retail and consumption. Maintaining the integrity of the cold chain is critical and is typically characterised by a network of cold storage warehouses and retail refrigeration units.

In many Asian countries several of these crucial intermediary links between the producer and consumer have not kept pace with consumer demand and expectations in food quality. Increased refrigeration will profoundly affect distribution costs and the environment due to fugitive refrigerant emissions and rising energy consumption and its associated carbon emissions. It is essential that refrigeration and space cooling systems operate efficiently (Box 20). Greening opportunities include:

Box 20: Cold storage warehouse energy and water efficiencies – Australia
(Storage SC 2007)

The Australian Government's Energy Efficiency Opportunities program requires businesses to identify, evaluate and report publicly on cost effective energy savings opportunities. Swine cold storage committed to reducing its CO_2, energy and water consumption by 15% in five years by:

- converting from Freon to ammonia which uses up to 30% less energy due to improved heat transfer;
- rapid roller doors to minimise heat ingress;
- energy management system to maximise room cycling, load sharing and shifting; and
- installation of LED lighting.

- **reducing heat loads** – effective roof and wall insulation, sealing to reduce air leaks, reduction in incidental heat loads from fans and pumps, lighting, people and machinery;
- **defrosting** on demand rather than by timer;
- **optimising compressor and system operations**, including the use of variable speed drives on fans, pumps and compressors and floating head pressures (allows the system to taking advantage of lower ambient temperatures to reduce refrigerant temperatures);
- **correctly sized condensers**;
- **temperature control and energy management systems**;
- **planned maintenance** to ensure effective heat transfer across surfaces;
- **use of natural refrigerants**;
- **recovery of compressor waste heat** for space or water heating; and
- **effective use** of cold space such as pallet racking.

Additional measures for refrigeration display cases in retail stores include optimising the hours of operation of anti-sweat heater controls and night covers (aluminium shields can reduce consumption by 8%) (Carbon Trust 2001).

8.2 Water

In retail and consumption, water is most often used for cleaning and to cool reject heat from refrigeration and air-conditioning units using evaporative condensing units (cooling towers). Opportunities to reduce water consumption include:

- **reduce cooling load of cooling towers and air conditioning** – reduce temperature set point and only operate when necessary;
- **reduce unnecessary water loss** – excessive flow from overflow and blowdown (effective water treatment to reduce number of concentration cycles), splashing, drift or leaks;
- **use of water efficient equipment** e.g. faucets, use of triggers mechanisms on hoses, maintenance of water equipment, shop design (surfaces and drains) and increasing staff and consumer awareness; and
- **dry cleaning techniques** e.g. soaking and using high-pressure, low-volume cleaning hoses.

8.3 Waste

Along with efficient refrigeration systems, waste can be prevented through effective and innovative packaging which has greatest opportunity for recycle and reuse. This is discussed further in section 5.8 (Packaging).

8.4 Consumer behaviour

As discussed, many Asian consumers purchase their daily food requirements at wet markets and local stores or kiosks. As Figure 5 indicates, increasing incomes; higher food quality and safety expectations; and urbanisation in industrialised Asia have all led to increased levels of consumer waste. Up to 30% of all food cooked is thrown away in Europe, North America and industrialised Asia. FAO estimates that if the food wasted or lost globally could be reduced by just one quarter, this would be sufficient to feed the 870 million people suffering from chronic hunger in the world (FAO 2013). In August 2013, FAO launched the 'Save Food Asia-Pacific Campaign', which will be an ongoing advocacy initiative. Another consumer awareness campaign is 'Love Food Hate Waste' (Box 21). This programme focuses on information about shopping habits, food storage, cooking and effective use of leftovers. The target audience is households and businesses such as the hospitality and retail sectors. Partnerships are formed with food retailers, manufacturers, not for profit organisations and local government.

Box 21: Awareness campaigns – UK
(Lipinski, Hanson et al. 2013)

More than 300 local authorities in England run localised "Love Food Hate Waste" initiatives to encourage and assist residents in reducing waste.

Worcestershire County Council undertook a three-month campaign to reduce food waste in Worcester City (9,000 households). Partnerships were formed with more than 70 local businesses, community organisations, and schools who displayed posters and distributed leaflets. The University of Worcester also hosted free cooking classes focused on effective reuse of leftovers. Food waste reduced by 14.7%.

9 DIRECTION FOR POLICY-MAKERS AND OTHER PLAYERS

This report has provided a multitude of suggestions for greening opportunities across the meat value chain. There is a small percentage of actors across meat value chains who use advanced technology and produce export- or high-quality chilled or frozen meat products and associated by-products. In Asia this amounts to no more than a few percent (Heinz 2008, Thapa 2009)). The intervention points in the value chain, those which offer the quickest or lowest cost environmental/economic efficiency returns, are very much dependent on the current operating stage of the individual business.

In rapidly growing economies where the livestock and meat processing sector is in the early stages of transition, smallholders need support to be able to participate in that transition. Similarly, more advanced meat processing facilities need support to remain competitive and to produce world class products. Appropriate interventions across meat supply chains are required to help increase productivity; meet increasingly stringent health and food-safety standards; reduce environmental impacts; and encourage best practice. These include the following:

- overarching government policy support and incentives;
- access to capital and credit for investment and other financial incentives e.g. tax breaks;
- access to knowledge and know-how on best practice technologies and support for technological innovations;
- capacity building programmes to improve or increase stakeholder competitiveness;
- improved distribution and transportation infrastructure i.e. cold chain supply; and
- improved communication infrastructure.

Some smallholders are unlikely to be able to compete as the meat supply chain becomes increasingly concentrated and linked to modern processing and marketing channels. These producers will require support as they leave the sector (adapted from (FAO 2009)).

In addition, to reduce environmental hazards associated with a fast-growing meat processing industry, governments need to develop and provide an environmental legislative framework supported by a regulatory system which is implemented and strictly enforced (Heinz 2008, UNIDO 2011). In this respect, international and national standards for hygienic processing and environmental management will also play a crucial role in lifting the standards of farming, processing, marketing and distribution of meat products. These include standards for Hazard Analysis Critical Control Point (HACCP); international (ISO) standards for quality and environmental management; and also export standards. The Codex Alimentarius (Book of Food) was established in 1963 by FAO and the World Health Organization (WHO) to provide governments and regional and international authorities with a recognised reference point on food safety and standards. The resource has a range of codes and standards for food processing, including meat (FAO and WHO 2013).

9.1 Policy development and stakeholder engagement

Successful policy-making will require the cooperation, interaction and integration with all stakeholders along the meat value chain, including government and non-governmental agencies, entrepreneurs, industry associations, research bodies, technical associations and suppliers (UNIDO 2011). In areas where regulations are not readily enforced, private-sector and trade associations can provide a good platform for clean technology information dissemination and improved results (Blackman and Kildegaard 2010). Assisting local businesses to develop technical knowledge, have access to internationally developed technologies and benefit from regional cooperation to provide local economies of scale, can help to ensure technical assistance is affordable and available locally (Heinz 2008).

To provide further direction, a review of existing policy recommendations from a number of leading organisations and specific to the meat value chain was undertaken for this report. These organisations include the FAO, UNIDO, the United Nations Environment Programme (UNEP) and Asian Development Bank (ADB). The recommendations are shown in Table 14 and linked with the corresponding section of this report which relates to that policy. It is envisaged that this will provide technical guidance on greening opportunities along the value chain to policy developers, non-governmental organisations and other organisations that provide assistance to the red meat processing industry. The table is aimed at policy developers, however, other main stakeholders have been highlighted.

Table 14: Greening opportunities in the meat value chain for policy developers

Greening opportunity	Reference	Key stakeholders (In addition to governments)	Related section of this report
General environmental policy development			
Development of national strategy on Sustainable Development and Sustainable Production and Consumption	(UNIDO 2011)	Industry groups	9
Cooperation between nations to develop sustainable policy with consistent standards, goals, targets and commitments.	(UNEP 2010) (UNIDO 2011)	International governments	9
Integrate environmental sustainability into regional and national development policies	(UNEP 2010)	UNEP	9
Market based instruments such as environmental taxes, environmentally motivated subsidies, tradable permits, and market prices that reflect ecological costs can promote resource efficiency.	(UNIDO 2011)	National government	9
Providing eco-efficiency infrastructure such as water, energy, wastewater treatment and recycling facilities	(UNIDO 2011)	Local and national government	9
Access to environmental data and information to assist in policy development.	(UNEP 2010)	UNEP, Science-based organisations	9
Research and technology development into livestock production	(ADB 2012)	Research facilities, Veterinaries	9
Support for individual business action			
Supporting the development and implementation of Environmental Management Systems.	(UNIDO 2011)	Individual businesses, industry groups	9
Development of industry based standards	(UNIDO 2011)	Industry groups	9
Supporting and promoting eco-labels and certification	(UNIDO 2011)	Third-party certification	9
Supporting and promoting life cycle analysis	(UNIDO 2011)	Individual businesses	9
Supporting and promoting greening of supply chains	(UNIDO 2011)	Individual businesses along the whole supply chain	9
Supporting and promoting corporate social responsibility	(UNIDO 2011)	Individual businesses	9
Supporting and promoting environmental accounting	(UNIDO 2011)	Individual businesses	9
Cleaner technology development			
Absorption and diffusion of cleaner technology through infrastructure such technology parks, clusters, global networks and by the provision of financial support instruments such as research and development grants, tax breaks, venture capital funds	(UNIDO 2011)	Research facilities, local technical businesses, technical associations	9
Developing an integrated and strategic science system to provide coherence between innovation and environmental policy.	(UNIDO 2011)	Research facilities	9

Greening opportunity	Reference	Key stakeholders (In addition to governments)	Related section of this report
Consumption			
Reduction of meat consumption in developed countries to allow increased consumption in developing countries without significant increase in livestock numbers.	(UNEP 2012)	Governments	8
Reduction of food waste.	(FAO 2013)	Governments	8
Better diets to improve nutrient absorption	(FAO 2009)	Governments	8
Greenhouse gas emissions			
Sustainable intensification of livestock and feed crop production to reduce carbon dioxide emissions from deforestation and pasture degradation	(FAO 2009)	Farmers, research facilities	4.3
Improved animal nutrition to cut methane	(FAO 2009)	Farmers, research facilities	4.3
Improved manure management nitrogen emissions	(FAO 2009)	Farmers, research facilities	4.3
Land degradation			
Restore damaged land through soil conservation	(FAO 2009)	Farmers	4.4
Silvopastoralism	(FAO 2009)	Farmers	4.4
Better management of grazing systems and protection of sensitive areas.	(FAO 2009)	Farmers	4.4
Water			
Better management of animal waste in industrial production units	(FAO 2009)	Research facilities, individual businesses	4.5 and 5.5
Improved manure management and better use of processed manure on croplands.	(FAO 2009)	Research facilities, farmers	4.5
Revitalise irrigation to unlock productivity gains	(ADB 2012)	Research facilities, farmers	4
Service-oriented approach to water management with more autonomy and accountability for irrigation service providers and farmer organisations.	(ADB 2012)	Farmers, service providers	4
Upgrading irrigation infrastructure using modern, smarter technologies.	(ADB 2012)	Research facilities, farmers	4
Biodiversity loss			
Improve protection of wild areas	(FAO 2009)	Farmers	4
Maintain connectivity among protected areas	(FAO 2009)	Farmers	4
Integrate livestock production and producers into landscape management.	(FAO 2009)	Farmers	4
Solid waste			
Turn organic solid waste into by-products for resale or use.	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	4 and 5.5
Minimise packaging	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	5.8
Switch to biodegradable packaging	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	5.8
Use recyclable packaging materials where possible.	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	5.8
Water cycle			
Closed-loop – Zero emission water system for reduction or total elimination of effluent from the manufacturing process.	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	5.4 and 6
Wastewater			
Use of wastewater treatment technologies beyond conventional secondary treatment.	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	5.4 and 6.3
Abattoir			
Set up demonstration facilities	FAO (Heinz 2008)	Research facilities, technical associations, individual businesses	4, 4.6 and 6
Provide specific abattoir sector training	FAO (Heinz 2008)	Research facilities, technical associations, individual businesses	4.6
Process control			
Improved sensor and process control to minimise waste and improve productivity	(UNIDO n.d.)	Research facilities, technical associations, individual businesses	4.6

10 CONCLUSION

This report highlights greening opportunities across the Asian beef supply chain. Livestock production presents the greatest challenge because it has the highest environmental impact, seen in greenhouse gas emissions; water extraction and use; land degradation and biodiversity loss. There are also social issues associated with animal husbandry and cropping. Taken together these are perhaps the hardest areas to deal with because of their widespread nature – there are literally millions of subsistence and small-scale commercial farming operations across Asia, with strong integration into established social activities. Intensification of livestock production also arguably exacerbates these issues.

Post-farming greening opportunities are potentially easier to manage, given that, in many cases, the impacts can be contributed to point source emissions of greenhouse gases, polluted wastewater and solid wastes. Technological solutions are available to address many of the impacts of post-farming. In this respect, grasping greening opportunities is more about the use of appropriate technologies and the ability to continually access finance and training opportunities via capacity building programmes.

Advances in greening the supply chain post-slaughter and in meat processing will generally occur in the use of refrigeration and extending the cold chain through to retail and domestic consumption. In doing so, more opportunities will open up in the production and sale of value-added meat products and by-products. With respect to retail and domestic consumption, the rise of the Asian middle class will continue to contribute significantly to a rapidly increasing demand for meat products. Consumer education programmes will become increasingly important in encouraging the efficient use of resources and will help to minimise waste.

The adoption of and adherence to international standards (safety, environment and risk), coupled with government and private partnerships, will help to ensure the production of safe, hygienic meat products and will aid in the development of the supply chain.

REFERENCES

Abberton, M., R. Conant and C. Batello (2009). Grassland carbon sequestration: management, policy and economics Proceedings of the Workshop on the role of grassland carbon sequestration in the mitigation of climate change. Rome, Italy, Food and Agriculture Organisation.

ADB. (2012). "Facts and Figures." Retrieved 21 August 2012, from http://www.adb.org/themes/climate-change/facts-figures.

ADB (2012). Food Security and Poverty in Asia and the Pacific: Key Challenges and Policy Issues, Asian Development Bank.

ADB. (2012, 12 August 2012). "The Water-Food-Energy Nexus." Retrieved 07/09/2013, from www.adb.org/features/water-food-energy-nexus.

ADRET (2012). Fuel for Thought - Identifying potential energy savings in the Australian road and rail sectors. Sydney NSW, Australian Department Of Resources Energy And Tourism.

AMPC and MLA (2003). Meat Technology Update, Optimising Blood Collection, Australian Meat Processing Corporation, Meat and Livestock Australia.

AMPC and MLA (2010). Meat Processing Best Practise Manual, Australian Meat Processing Corporation, Meat and Livestock Australia,.

Andrew, M. and Y. Peng (2012). The Rise of the Middle Class in Asian Emerging Markets. KPMG, KPMG.

Angus Lawson (2012). Beef Cattle Artificial Insemination Synchrony Programs. Beef Industry News & Insights on Genetics, AI, Animal Health and Marketing.

APEDA (2008). Indian Meat Industry Red Meat Manual, Ch 2. , Indian Agricultural and Processed Food Products Export Development Authority

APEDA (2013). Approved Indian abattoirs-cum-meat processing plants/abattoirs, Agricultural and Processed Food Products Export Development Authority.

APEDA AgriXchange (2013). India Export of Agro Food Products. Product Group Report/Country Wise. Agricultural and Processed Food Products Export Development Authority (APEDA). agriexchange.apeda.gov.in/About_Agri_Exchange.aspx.

Armbruster, W. and W. Coyle (2004). Pacific Food System Outlook 2004-2005: The role of transportation infrastructure in a seamless food system, PECC.

Arthurson, V. (2009). "Closing the Global Energy and Nutrient Cycles through Application of Biogas Residue to Agricultural Land – Potential Benefits and Drawback." Energies 2(2): 226-242.

Australian Department of Agriculture Fisheries and Forestry (2012). Demonstrating the minimisation of GHG emissions through improved paunch management. Climate Change Research Program. Canberra.

Australian Livestock Exports. (2013). "Australian Beef Cattle Exports." from www.australianlivestockexports.com.au/Australian-Beef-Cattle-Exports.html.

Australian Meat Processing Corporation (AMPC) and Meat and Livestock Australia (MLA) (2002). "Composting of slaughterhouse material and dead stock." Meat Technology Update Newsletter 02/5.

Beauchemin, K. A., M. Kreuzer, F. O'Mara and T. A. McAllister (2008). "Nutritional management for enteric methane abatement: a review." Australian Journal of Experimental Agriculture 48: 21-27.

Beef Central. (2012). "India takes over as world's largest beef exporter." from www.beefcentral.com/p/news/article/2239.

Blackman, A. and A. Kildegaard (2010). "Clean technological change in developing-country industrial clusters: Mexican leather tanning." Environmental Economics and Policy Studies 12(3): 115-132.

Block, B. (2013). "Asian Water Supplies Require Substantial Overhaul." from www.worldwatch.org/node/6235.

BMT Surveys. (n.d.). " CargoHandbook Leather." Retrieved 19/08/2013, from www.cargohandbook.com/index.php/Leather.

Bridle, T. (2011). Pilot testing pyrolysis systems and reviews of solid waste use on boilers. Sydney, Meat and Livestock Australia.

Canning, P., A. Charles, S. Huang, K. R. Polenske and A. Waters (2010). Energy Use in the U.S. Food System, United States Department of Agriculture Economic Research Service.

Carbon Trust (2001). Refrigeration Road Map UK.

Center for Natural Resource Information Technology, T. A. M. U. S. (2013). "An Early Warning System for Livestock in the Gobi Region of Mongolia." Retrieved 15th August, 2013, from cnrit.tamu.edu/pagesmith/38.

Centre Technique Cuir chaussure Maroquinerie (2000). Wastes in the Leather Industry. Fourteenth Session of the Leather and Leather Products Industry Panel.

Chand, R., P. Kumar, S. Raju, P. Shinoj and K. Rich (2007). Biofuels and the poor - Case study India Bill & Melinda Gates Foundation.

Chander, M. (2010). Urea treatment of straw:hugely extolled rarely used Proceedings of the FAO Electronic Conference - Successes and failures with animal nutrition practices and technologies in developing countries. Makkar.H. Rome, Itlay, Food and Agriculture Organisation.

ChemStation. (2013). "Meat Processing Chemicals." from www.chemstationchesapeake.com.

Claxton, R. (2013). Increasing Asian meat demand creates opportunities and is a major factor in supporting global livestock prices. Available at www.girafood.com. Gira Asia Meat Club, Gira Food.

Cleaner Production Institute. (2009). "Sustainable Cleaner Production in the Manufacturing Industries of Pakistan, Simplified Life Cycle Assessment Hot Spot Identification in the Leather Production Chain." Retrieved 19/08/2013, from www.cpi.org.pk.

Commercial Transport Publishing Ltd (2011). Global Cold Chain News - Feb 2011. Helston, UK

Coughenour, M. and M. H. (2012). Conducting national feed assessments. Animal Production and Health Manual No. 15. . Rome, Italy, Food and Agriculture Organisation.

CSIRO. (2011). "Cleaning and sanitation in food processing areas." from www.csiro.au/Outcomes/Food-and-Agriculture/Food-processing-areas-cleaning.aspx.

Dixon, R., A. Gulliver and D. Gibson (2001). Farming Systems and Poverty - Improving Farmers Livehoods in a Changing World Rome, Italy, Food and Agriculture Organisation.

Donnges, C., G. Edmonds and B. Johannessen (2007). Rural Road Maintenance - Sustaining the Benefits of Improved Access (SETP 19). Bangkok, Thailand, International Labour Organization.

European Commission. (2013, 04/02/2013). "REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals." Retrieved 23/09/2013, from ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm.

FAO (2009). The State of Food and Agriculture, Livestock in the balance, Food and Agriculture Organisation.

FAO. (2011). "FAOSTATS - Downloads 2011." from faostat3.fao.org/home/index.html#DOWNLOAD.

FAO (2011). OECD-FAO Agricultural Outlook 2011-2020. Agricultural Outlook, Food and Agriculture Organisation.

FAO (2012). Growing greenhouse gas emissions due to meat production, UNEP Global Environmental Alert Service, Food and Agriculture Organisation.

FAO. (2013). "Save food campaign Asia-Pacific kicked off " Retrieved 2nd September, 2103, from www.fao.org/news/story/en/item/195565/icode/.

FAO (2013). State of Food and Agriculture, Food and Agriculture Organisation.

FAO (2013). Trends and impacts of foreign investment in developing country agriculture, Food and Agriculture Organisation.

FAO (2013). Climate Smart Agriculture Source Food and Agriculture Organisation.

FAO and WHO. (2013). "CODEX Alimentarius, International Food Standards." Retrieved 23/09/2013, from www.codexalimentarius.org/.

Faures, J. and A. Mukherji (n.d.). Trends and Drivers of Asian Irrigation, FAO and IWMI

Franklin, S., J. Jordan, P. McCracken, J. McDonald and J. Gordon (2010). Renewable energy and energy efficiency options for the Australian meat processing industry. North Sydney, Meat and Livestock Australia.

Frendrup, W. (2000). Hair-saving Unhairing Methods in Leather Processing, United Nations Industrial Development Organization.

Garg, M. (2012). Balanced feeding for improving livestock productivity – Increase in milk production and nutrient use ef? ciency and decrease in methane emission. Animal Production and Health Paper Rome, Italy, Food and Agriculture Organisation.

Garg, R. and M. Bhanderi (2011). Enhancing livestock productivity through balanced feeding. 14th biennial Conference of the Animal Nutritional Society of India, Pantnagar University of Agriculture and Technology, Pantnagar, Uttra Khand, India.

Gerber, P., A. Hristov, B. Henderson, H. Makkar, J. Oh, C. Lee, R. Meinen, F. Montes, T. Ott, J. Firkins, A. Rotz, C. Dell, A. Adesogan, W. Yang, J. Tricarico, E. Kebreab, G. Waghorn, J. Dijkstra and S. Oosting (2013). "Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: a review." Animal 7(s2): 220-234.

Ghosh, P. (2013) "Where's the beef? In India, Believe it or not." International Business Times.

Giamalva, J. (2013). "Korea's Demand for US Beef." Journal of International Commerce and Economics.

Gómez, M. I. and K. Ricketts (2012). Food value chains and policies influencing nutritional outcomes. Rome, Background paper for The State of Food and Agriculture 2013: Food systems for better nutrition.

Government of Alberta (2011). Quantification protocol for reducing the age at harvest of beef cattle.

Gustavsson, J., C. Cederberg, U. Sonesson, R. van Otterdijk and A. Meybeck (2011). Global Food Losses and Food Waste, Extent Causes and Prevention, Food and Agriculture Organisation.

Hadi, P., N. Ilham, A. Thahar, B. Winarso, D. Vincent and D. Quirke (2002). Improving Indonesia's Beef Industry, ACIAR.

Harris, S. and V. Narayanaswamy (2009). A Literature Review of Life Cycle Assessment in Agriculture, Rural Industries Research and Development Corporation.

Hasan, M. H., T. M. I. Mahlia and H. Nur (2012). "A review on energy scenario and sustainable energy in Indonesia." Renewable and Sustainable Energy Reviews 16(4): 2316-2328.

Hayes, B., P. Bowman, A. Chamberlain and M. Goddard (2009). "Genomic selection in dairy cattle: progress and challenges." J. Dairy Sci. 92: 433–443.

Hayes, B., H. Lewin and M. Goddard (2013). "The future of livestock breeding:genomic selection for ef? ciency, reduced emissions intensity, and adaptation." Trends in Genetics Vol. 29(4).

Heinz, G. (2008). Abattoir Development Options and Designs for Hygienic Basic and Medium-Sized Abattoirs Food and Agriculture Organisation.

Heinz, G. and P. Hautzinger (2007). Meat Processing Technology for Small to Medium Producers, Food and Agriculture Organisation.

Hristov, A. N., J. Oh, C. Lee, R. Meinen, F. Montes, T. Ott, J. Firkins, A. Rotz, C. Dell, A. Adesogan, W. Yang, J. Tricarico, E. Kebreab, G. Waghorn, J. Dijkstra and S. Oosting (2013). Mitigation of Greenhouse Gas Emissions in Livestock Production A review technical options for non-CO2 emissions. Rome, Italy., Food and Agriculture Organisation of the United Nations. 177.

Huang, J. (2013). Financing sustainable agriculture under climate change with a specific focus on foreign aid, UNU-WIDER project 'ReCom—Research and Communication on Foreign Aid'.

Huffer, S. and T. Taeger (2004). "Sustainable leather manufacturing a topic with growing importance." Journal of American Leather Chemists Association 99(10): 423-428.

IAEA (2009). Selection and Breeding of Cattle in Asia: Strategies and Criteria for Improved Breeding. Vienna, Austria, Animal Production and Health Section International Atomic Energy Agency.

ICRISAT (2009). Fertiliser Microdozing - Boosting Production in Unproductivity Lands, International Crops Research Institute for Semi-Arid Tropics.

IFAD (2011). Smallholder Farming in Asia and the Pacific: Challenges and Opportunities. Conference on New Directions for Smallholder Agriculture, Rome, Italy International Fund for Agricultural Development,.

INCCA (2010). Indian Network for Climate Change Assessment. India: Greenhouse Gas Commission 2007, Indian Network for Climate Change Assessment, Ministry of Environment & Forests, Government of India

Indian CED (2011). Solid Waste Management in Slaughterhouse, Indian Centre for Environment and Development

Ingle, K., K. Harada, C. Wei, K. Minamoto and A. Ueda (2011). "Policy framework for formulating environmental management strategy for sustainable development of tanneries in India." Environmental Health and Preventive Medicine 16(2): 123-128.

Ingrid, H. F.-W. and I. Heribert (2012). "Treatment alternatives of slaughterhouse wastes, and their effect on the inactivation of different pathogens: A review." Critical Reviews in Microbiology 39(2).

International Trade Centre. (n.d.). "Leather." Retrieved 15/08/2013, from www.intracen.org/exporters/leather/.

International Water Management Insitute (2000). Projected water scarcity in 2050

International Water Management Insitute (2010). Water Issue Brief: Revitalizing irrigation.

ITC. (2013). "e-CHOUPAL." from www.itcportal.com/businesses/agri-business/e-choupal.aspx.

IUE. (2008). "Recommendations on Cleaner Technologies for leather production." Retrieved 22/08/2013, from www.iultcs.org/pdf/IUE1_2008.pdf.

Jamsranjav, C. (2009). Sustainable Rangeland Management in Mongolia: The role of herder community institutions Land Restoration Training Programme Iceland.

Jensen, E., M. Peoples, R. Boddey, P. Gresshoff, H. Hauggaard-Nielsen, B. Alves and M. Morrison (2012). "Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review " Agronomy for Systainable Development 32(2): 29-364.

Joseph, K. and N. Nithya (2009). "Material flows in the life cycle of leather." Journal of Cleaner Production 17(7): 676-682.

Khanum, S., M. Hussain, H. Hussain and M. Ishaq (2010). Impact of urea-molassesmultinutrient block supplementation on livestock production in Pakistan. FAO Electronic Conference - Successes and failures with animal nutrition practices and technologies in developing countries. H. Makkar. Rome, Italy., FAO.

Krishnamoorthy, G., S. Sadulla, P. K. Sehgal and A. B. Mandal (2012). "Green chemistry approaches to leather tanning process for making chrome-free leather by unnatural amino acids." Journal of Hazardous Materials 215–216(0): 173-182.

Larson, E. e. (2008). Biofuel production technologies: status, prospects and implications for trade and development. . United Nations Conference on Trade and Development, New York and Geneva.

Leahy, S., W. Kelly, R. Ronimus, N. Wedlock, E. Altermann and G. Attwood (2013). "Genome sequencing of rumen bacteria and archaea and its application to methane mitigation strategies." Animal 7(s2): 235–243.

Leddin, C., N. Ba, N. Van, L. Ngoan and P. Doyle (2011). Case Study 3: Improved beef production in central Vietnam. Beef production in crop-livestock systems: simple approaches for complex problems. B. Winter. Canberra, Australian Centre for International Agricultural Research.

Leip A, Weiss F, Wassenaar T, Pérez Domínguez I, Fellmann T, Loudjani P, Tubiello F, Grandgirard D, Monni S and Biala K (2010). The GGELS Project: European Greenhouse Gases Emissions from Livestock Production Systems, Dictus Publishing.

Levonian, R. (2013). Co-products Brief, Trends in Australian co-product values for June quarter 2013, Meat and Livestock Australia.

Li, H., H. Gao, J. Chen, W. Li and R. Li. (2000). "Study on controlled traf? c with conservation tillage." Trans. C. S. A. E. 16:: 73-77.

Lipinski, B., C. Hanson, J. Lomax, L. Kitinoja, R. Waite and T. Searchinger (2013). Reducing Food Loss and Waste - Working Paper, World Resource Insititute.

Liu, D.-C. (2011). "Better Utilization of By-Products from the Meat Industry." Department of Animal Science, National Chung-Hsing University.

Lu, X., J. Fan and J. Liu (2006). Grassland resource in:'Chinese grassland sustainable development strategy' Beijing, China Chinese Agricultural Press.

Ludvik, J. (2000). Chrome Balance in Leather Processing, United National Industrial Development Organization.

Ludvik, J. (2000). Chrome Management in the Tanyard, United Nations Industrial Development Organization.

Ludvik, J. (2000). The scope for decreasing pollution load in leather processing, United Nations Industrial Development Organization.

MacLeod, M., P. Gerber, C. Opio, A. Falcucci, G. Tempio and H. Steinfeld (2012). FAO's global livestock life-cycle analysis: current state of play and forthcoming initiatives. Partnership Technical Seminar. Food and Agriculture Organisation.

Makkar, H. (2013). Feed and fodder challenges for Asia and the Pacific - Asian Livestock: Challenges, opportunities and the response. . Proceedings of an International Policy Forum, Bangkok, Thailand, Ahuja, V.

McKinsey & Company (2009). China's Green Revolution: prioritizing technologies to achieve energy and environmental sustainability. London.

MLA (2008). Red Meat Processing Industry Energy Efficiency Manual, Meat and Livestock Australia

MLA (2013) "Australia represents 43% of China's red meat imports in 2012-13, Available at www.mla.com.au." Market News.

Mogensen, L., J. E. Hermansen, N. Halberg and R. Dalgaard (2008). Life Cycle Assessment across the Food Supply Chain Sustainability in the Food Industry

Mongolian Society for Range Management (2010). Livelihood Study of Herders in Mongolia. Ulaanbaatar, MSRM and Swiss Agency for Development and Cooperation SDC.

Musa, A. E., B. Madhan, S. Kanth, J. R. Rao, B. Chandrasekaran and G. A. Gasmelseed (2010). "Cleaner tanning process for the manufacture of upper leathers." Clean Technologies and Environmental Policy 12(4): 381-388.

myclimate – The Climate Protection Partnership (2012). From cow dung to biogas in Karnataka, India. Switzerland.

Nepal Biomass Support Program (2012). Year Book.

Nierenberg, D. and L. Reynolds (2012) "Disease and drought curb meat production and consumption." Vital Signs Online.

Oenema, O. (2006). "Nitrogen budgets and losses in livestock systems." International Congress Series 1293(262–271).

Özgünay, H., S. Çolak, G. Zengin, Ö. Sari, H. Sarikahya and L. Yüceer (2007). "Performance and emission study of biodiesel from leather industry pre-fleshings." Waste Management 27(12): 1897-1901.

Pagan, R., P. Prasad, N. Price and E. Kemp (2004). Ecoefficiency for the Queensland Food Processing Industry, Australian Industry Group.

Pagan, R., M. Renouf and P. Prasad (2002). Ecoefficiency Manual for Meat Processing, Meat and Livestock Australia.

Peters, G., S. Wiedemann, H. Rowley and R. Tucker (2010). "Accounting for water use in Australian red meat production." International Journal of Life Cycle Assessment.

Peters, G. M., H. V. Rowley, S. Wiedemann, R. Tucker, M. D. Short and M. Schulz (2010). "Red Meat Production in Australia: Life Cycle Assessment and Comparison with Overseas Studies." Environmental Science & Technology 44(4): 1327-1332.

Pittards. (2013). "Discover Pittards, Continuous Improvement Projects." Retrieved 02/09/2013, from www.pittards.com/discover-pittards/91/environmental-continuous-improvement-projects.

Puentener, A. (2004). "Disposal of leather goods." Retrieved 17/08/2013, from www.tfl.com/web/files/disposalleathergoods.pdf.

Rajamani, S., Z. G. Chen and S. H. Zhang. (2009). "Recent developments in cleaner production and environment protection in world leather sector." XXX Congress Int. Union Leather Technol. Chem. Soc, from www.aaqtic.org.ar/congresos/china2009/oralPresentation/1-10.pdf.

Reardon, T. and A. Gulati (2008). The rise of supermarkets and their development implications: international experience relevant for India. IFPRI Discussion Paper No. 00752. Washington, DC, IFPRI.

Reardon, T. and C. P. Timmer (2012). The Economics of the Food System Revolution. The Annual Review of Resource Economics, 4: 225–264.

Ren, J. Z., Z. Z. Hu, J. Zhao, D. G. Zhang, F. J. Hou, H. L. Lin and X. D. Mu (2008). "A grassland classi? cation system and its application in China " The Rangeland Journal 30: 199–209.

Retamel, M., A. Turner and S. White (2009). The Water–Energy–Climate Nexus—systems Thinking and Virtuous Circles. Climate Change and Water: International Perspectives on Mitigation and Adaptation International Water Association.

Ricklefs, C. and M. Xhunga. (2010). "ecoFridge: Emissions free and silent running."

Ridoutt, B. G., P. Sanguansri, M. Freer and G. S. Harper (2012). "Water footprint of livestock: comparison of six geographically defined beef production systems." The International Journal of Life Cycle Assessment 17(2): 165-175.

Ridoutt, B. G., P. Sanguansri and G. S. Harper (2011). "Comparing Carbon and Water Footprints for Beef Cattle Production in Southern Australia." Sustainability 3(12): 2443-2455.

Rosegrant, M., X. Cai and S. Cline (2002). Global water outlook to 2005, Averting an impending crisis. A 2020 vision for food, agriculture and the environment initative International Food Policy Insitute and International Water Management

Schmidinger, K. and E. Stehfest (2012). "Including CO2 implications of land occupation in LCAs—method and example for livestock products." The International Journal of Life Cycle Assessment 17(8): 962-972.

Scollan, N., D. Moran, E. Kim and C. Thomas (2010). Report to the International Meat Secretariat - The environmental impacts of meat production.

Shanwad, U., V. Patil and H. Gowda (2004). Precision Farming: Dreams and Realities for Indian Agriculture. Map India 2004.

Siddharth, J. and M. P. Sharma (2011). "Power generation from MSW of Haridwar city: A feasibility study." Renewable and Sustainable Energy Reviews 15(1): 69-90.

Singh, R. (2011). India - Livestock and Products Annual, USAD.

Sivakumar, V., K. Jeyaraj, R. Chandrasekar and G. Swaminathan. (2008). "Tanning Alternatives." 10 July 2008. Retrieved 15/08/2013, from www.leathermag.com/features/featuretanning-alternatives.

Spence, J. (2012). Renewable Energy in the Australian Red Meat Processing Industry & The Viability of Paunch as a Biofuel. Masters Dissertation. University of Southern Queensland

Springfeld, H., P. Geber, T. Wassenaar, V. Castel, M. Rosales and C. de Hanns (2006). Livestocks long shadow - environmental issues and options. Rome, Itlay, FAO.

Storage SC. (2007). "Swine Cold Storage - Environment Australia2007 " Retrieved 2 September 2013, from www.swirecoldstorage.com.au/default.asp?section_id=22.

Suzuki, T. (2006). "Reseaerch Highlights 2005 - Utilization of sugarcane silage as feed for beef cattle in Northeast Thailand." Retrieved 7th August, 2013, from www.jircas.affrc.go.jp/english/publication/highlights/2005/2005_12.html.

Szabo, C. and V. Halas (2012). LIvestick production as a technological and social challenge - emphasis on sustainability and precision nutrition. 20th Int. Symp. “Animal Science Days”. Kranjska Gora, Slovenia.

Thapa, G. (2009). Smallholder Farming in Transforming Economies of Asia and the Pacific: Challenges and Opportunities Thirtythird session of IFAD's Governing Council.

Thapa, G. (2009). Smallholder Farming in Transforming Economies of Asia and the Pacific: Challenges and Opportunities Thirtythird session of IFAD's Governing Council; 18th Feb 2009.

The Leather Working Group. (n.d.). "The Leather Working Group." Retrieved 02/09/2013, from www.leatherworkinggroup.com/.

The Poultry Site. (2005, 14 November 2005). "Assessing The Results of the EU Ban on Antibiotic Feed Additives." Retrieved 09/09/2013, from www.thepoultrysite.com/articles/471/assessing-the-results-of-the-eu-ban-on-antibiotic-feed-additives

Trimble, S. and A. Mendel (1995). "The cow as a geomorphic agent : A critical reveiw." Geomorphology 13: 233-253.

UN (2011). Statistical Yearbook for Asia and the Pacific 2011. Thailand

UNEP (2010). UNEP Six Priority Areas Factsheets - Environmental governance. United Nations Environment Program. Kenya, UNEP.

UNEP (2012). Growing greenhouse gas emissions due to meat production, United Nations Environment Program.

UNIDO (2011). Industrial Policy for Prosperity: UNIDO's Strategic Support. United Nations Industrial Development Organization.

UNIDO (2011). Introduction to treatment of tannery effluent, What every tanner should know about effluent treatment. Vienna, United National Industrial Development Organisation.

UNIDO (2011). UNIDO Green Industry. Policy for Supporting Green Industry. Vienna, United Nations Industrial Development Organization.

UNIDO (n.d.). 25) Pollution from food processing factories and environmental protection: 1-11.

US Energy Information Administration. (2011). "International Energy Statistics, By Country." from www.eiq.gov/countries.

van Kempen, T. and S. T. (1997). "Near-Infrared reflectance Spectroscopy in precision Feed Formulation. ." Journal of Applied Poultry Resesearch 6(4): 471-477.

Van Ness, W. J. (2006). "Asia hits the gas, Biogas from anaerobic digestion rolls out across Asia." Renewable Energy World(Jan-Feb).

VDEPI. (2011). "Grape by-product cuts dairy emissions by 20 per cent." Retrieved 9th August, 2013, from www.dpi.vic.gov.au/agriculture/about-agriculture/newsletters-and-updates/ag-in-focus/ag-in-focus-summer-2012/grape-by-product-cuts-dairy-emissions-by-20-per-cent.

Veal, D. (2008). Presentation: High Value Animal Derived Products Market Opportunities and Pitfalls, Meat and Livestock Australia.

Walli, T., M. Garg and H. Makkar (2012). Crop residue based densi? ed total mixed ration – A user-friendly approach to utilise food crop by-products for ruminant production. FAO Animal Production and Health Paper Rome, FAO. 172.

Weiss, F. and A. Leip (2012). "Greenhouse gas emissions from the EU livestock sector: A life cycle assessment carried out with the CAPRI model." Agriculture, Ecosystems & Environment 149(0): 124-134.

White, T., M. Johns and B. Butler (2013). Methane Recovery and Use at a Meat Processing Facility, Rural Industries Research and Development Organisation (RIRDC). Publication No. 13/027.

Yang, W., M. Oba and T. McAllister (2012). "Precision processing maximizes the feed value of barley grain for feedlot cattle." Prairie Post Bull Breeders February (12-13).

Zhang, J. (2002). "Experimental study on controlled traf? c farming." Shanxi Agric. Machinery 16: 22-25.