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Understanding the Food Energy Water Nexus

Energy as an input in the food value chain

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ABOUT THIS STUDY

Food, water and energy security form the basis of a self-sufficient economy, but as a water-scarce country with little arable land and a dependence on oil imports, South Africa's economy is testing the limits of its resource constraints. WWF believes that a possible crisis in any of the three systems will directly affect the other two and that such a crisis may be imminent as the era of inexpensive food draws to a close.

WWF received funding from the British High Commission to establish a research programme exploring the complex relationship between food, water and energy systems from the perspective of a sustainable and secure future for the country. This paper is one of nine papers in the Food Energy Water Nexus Study.

PAPERS IN THIS STUDY

1. *Climate change, the Food Energy Water Nexus and food security in South Africa:* Suzanne Carter and Manisha Gulati
2. *Developing an understanding of the energy implications of wasted food and waste disposal:* Philippa Notten, Tjasa Bole-Rentel and Natasha Rambaran
3. *Energy as an input in the food value chain:* Kyle Mason-Jones, Philippa Notten and Natasha Rambaran
4. *Food inflation and financial flows:* David Hampton and Kate Weinberg
5. *The importance of water quality to the food industry in South Africa:* Paul Oberholster and Anna-Maria Botha
6. *The agricultural sector as a biofuels producer in South Africa:* Alan Brent
7. *Virtual water:* James Dabrowski
8. *Water as an input into the food value chain:* Hannah Baleta and Guy Pegram
9. *Water, energy and food: A Review of integrated planning in South Africa:* Sumayya Goga and Guy Pegram

ABOUT WWF

The World Wide Fund for Nature is one of the World's largest and most respected independent conservation organisations, with almost five million supporters and a global network active in over 100 countries. WWF's mission is to stop the degradation of the Earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

DISCLAIMER

CITATION

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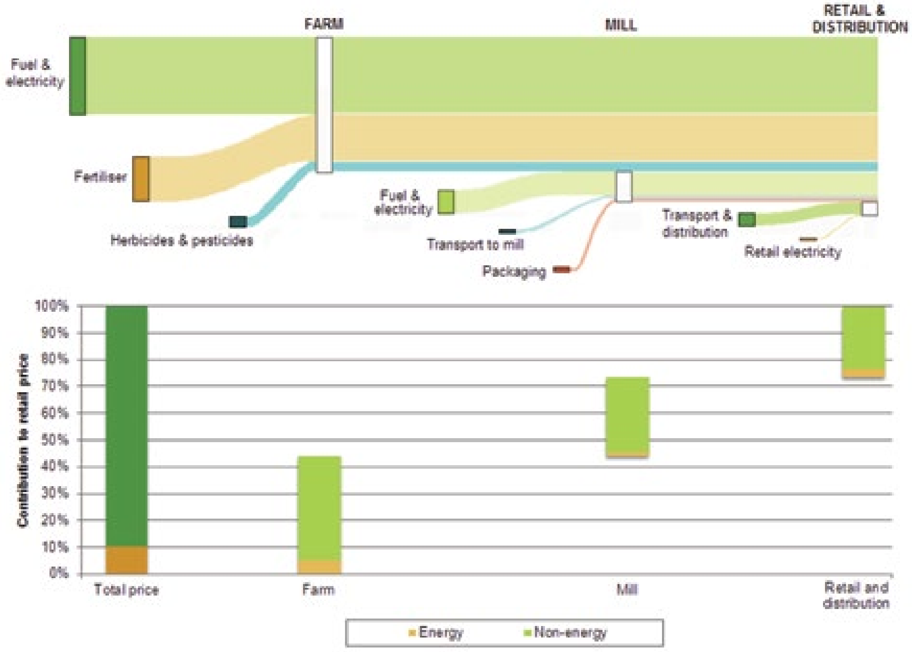
ABSTRACT

Energy prices have increased dramatically in recent years, both in South Africa and globally, and food prices have seen above-average inflation. This has stimulated debate about the relationship between energy prices, food inflation and food security for the poor. This paper examines the relationship between energy prices and food security in South Africa. An examination of South African food statistics reveals that food security is lacking for many households. This arises primarily as a result of affordability problems, as there appears to be adequate food available in the country: most households would be able to utilise food if they could access it. Food price increases are therefore likely to directly and significantly reduce food security.

Having demonstrated the key importance of affordability to food security, an examination of case-study foods, maize, potatoes, apples, chicken, milk and fish, illustrates the role of energy in food provision from a life-cycle perspective. The direct energy use of the food and agriculture industries is taken into account (electricity and fuel), as well as the energy needed by other industries to produce important material inputs like fertiliser and packaging. This analysis reveals quite varied energy-use patterns between the farm, food processing and retail stages of the value chain for the different case study foods, and a general tendency for energy use to be concentrated at earlier stages of the value chain, particularly before the farm gate. By contrast, an analysis of price development across the value chain for the different case study foods found that price contributions to final retail price tended to be more equally spread across the value chain or weighted towards the latter stages of the value chain. Thus, the price contributions of different value chain stages do not appear to be proportionally related to their energy intensity. Data limitations preclude a comprehensive analysis of energy price influences across each stage of the value chain, but an illustrative calculation can be developed for maize meal, as shown in Figure A1. This reflects the flows of energy in absolute (megajoule) terms at the top of the diagram, through each value chain stage, and a parallel development of price at the bottom, showing the energy cost share at each stage.

Figure A1 provides a number of interesting observations. First, it is clear that energy is a significant but not dominant contributor to the retail price of maize. It is also interesting that the cost shares of energy at the different value stages are not related to the absolute amounts of energy they consume. Other cost contributors and the form of energy also have significant influences. For example, the transport energy reflected under retail and distribution is a minor proportion of overall energy use, but makes a greater contribution to total price than the much larger amount of energy consumed before the farm gate. This is a reflection of the higher cost of diesel fuels for transport (the main energy form at this stage) compared to farm electricity and coal or natural gas for fertiliser manufacture. Furthermore, the impact of an energy price increase at farm level on the retail price would appear to be dampened along the value chain, first by the other cost components on the farm, and then by the price mark-ups at the subsequent value chain stages.

Figure A1: Energy share contribution to retail price in the maize value chain



It is clear that the translation of energy cost along the supply chain is not straightforward, and an energy price increase should not be expected to induce a proportional increase in food prices. This is evident from the energy and cost shares across the value chains of the case study examples, even without considering the plethora of further complications such as international markets, exchange rates, price negotiation dynamics in the supply chain, or anticompetitive pricing practices. The effect of an energy price increase on food prices – and thereby on food security – is highly dependent on where energy is used, what share of cost it represents, what proportion of retail price it commands and whether this price can be passed on to the buyer.

KEY WORDS

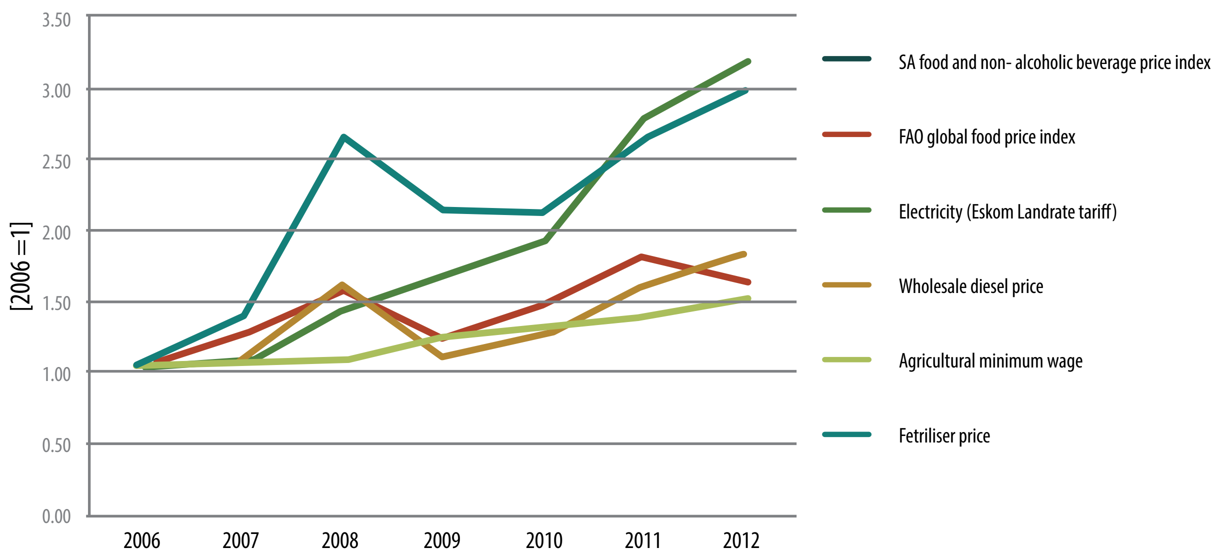
Food value chain, food supply chain, food cost, energy cost, energy input.

CONTENTS

1. INTRODUCTION

Energy prices have increased dramatically in recent years, both in South Africa and globally, and food prices have seen above-average inflation (Jooste 2012). Some relevant price measures for recent years are shown in Figure 1, including South African food and energy prices. The increases have stimulated debate about the relationship between high energy prices and recent food inflation and, by extension, the impact on food security for the poor. A recent World Bank study analysed historical energy and food price movements globally, and concluded that increases in crude-oil prices account for more than 50% of food price increases seen in bulk commodity markets (Baffes and Dennis 2013). It has also been argued that energy price increases can significantly impact on the affordability of food in South Africa (Gulati et al. 2013). WWF-SA commissioned this paper to explore the interrelationship between energy prices and food security in South Africa.

Figure 1: Selected price trends, with 2006 = 1 basis point



This paper starts from the definition of food security adopted at the World Food Summit in 1996 (StatsSA 2012a): Food security exists when all people, at all times, have physical and economic access to sufficient, afe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

As this suggests, there are several aspects to food security, which can be disaggregated as follows (FAO 2006):

- Food availability: the availability of sufficient quantities of food of adequate quality.
- Food access: the ability to access the available food, including the economic, legal, political and social capacity for obtaining such access.
- Stability: an existing ability to acquire and use food as well as a stability of supply and safety from risk.
- Utilisation: the capacity to safely and effectively utilise food, which includes having an adequate diet to maintain good nutrition, and non-food elements such as access to clean water and sanitation.

In section 2, food security in South Africa is examined using this framework. The energy and cost profile of food production for a set of case-study foods is then investigated in section 3, to demonstrate how different stages in the food supply chains contribute to life-cycle energy requirements and total cost for different commodities. These case studies provide useful insights that are further explored in section 4, where additional analysis reveals some of the complexities and implications relating to energy price increases in the food system. The paper closes with a summary of the main observations and conclusions.

2. FOOD PRODUCTION AND FOOD SECURITY IN SOUTH AFRICA

Systems of food production, processing and trade are complex, but agricultural statistics show that South Africa does not face a fundamental shortage of food. Table 1 presents total and per capita production of selected foodstuffs. This table is not a complete representation of South Africa's agricultural production, but allows for a daily serving of ample grains, over 100 g of meat and some vegetables. Although about 40% of maize production is actually used as animal feed (DAFF 2012b), the table nevertheless indicates that a reasonable level of nutrition would in principle be possible, without considering food imports. Furthermore, South Africa's extensive transport network could support food delivery to most areas of the country. Hence the food availability dimension of food security does not seem to be of concern at present.

Table 1: Total and per capita production of selected foods in South Africa in 2011

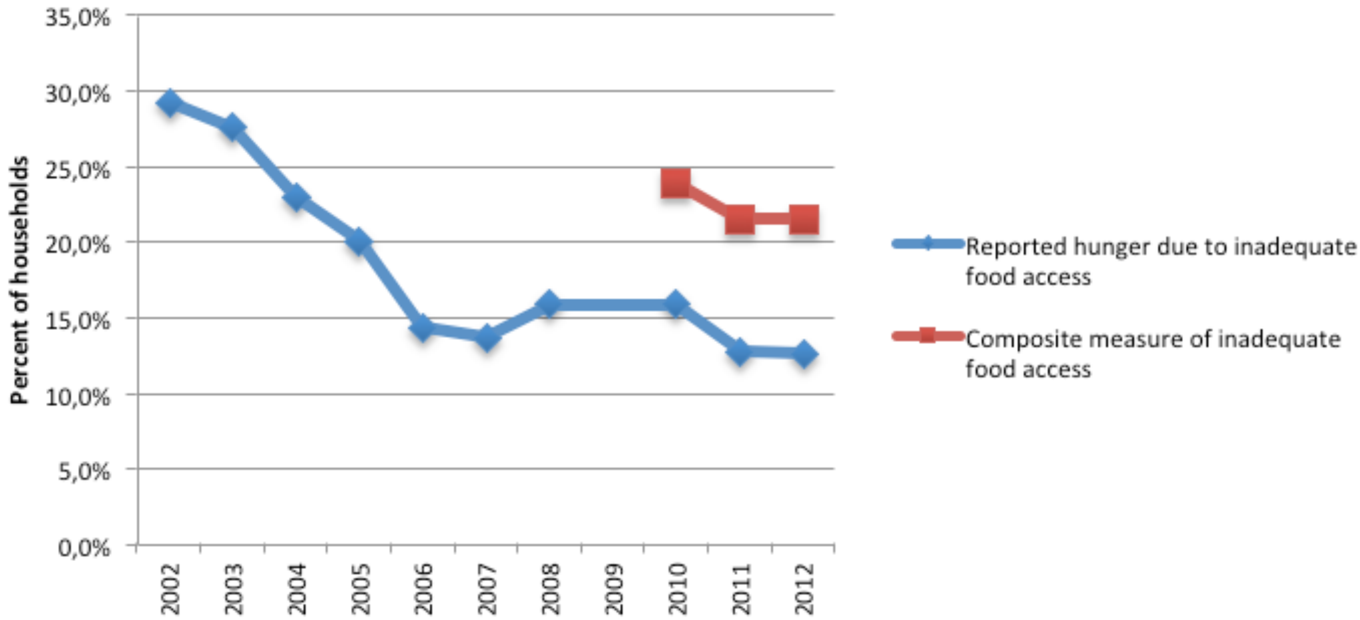
Product	Production (tonnes)	Per capita production (g/person-day)
Maize	13 421 000	710
Wheat	2 050 000	108
Cabbage	150 913	8
Lettuce	36 000	2
Carrots	160 000	8
Tomatoes	500 000	26
Potatoes	2 196 612	116
Chicken	1 400 000	74
Beef	819 600	43

Compiled from: DAFF (2012a); StatsSA (2012b)

Although South Africa evidently has sufficient food availability to satisfy the needs of the population, food security is nonetheless lacking for many people. Figure 2 shows two measures of food access from StatsSA's General Household Surveys. In this figure, "reported hunger" shows people's response to the question of whether members of their household have gone hungry due to a lack of food. The composite measure is a more sophisticated index of household food insecurity that draws on a number of questions probing the household's food-related activities. These measures show a significant proportion of households as having inadequate access to food, although the reported incidence of hunger has been declining steadily. Reporting these figures as an average, however, conceals a great deal of variation between income groups. Food access insecurity is much more common among lower-income groups, exceeding 40% for the poorest fifth of households, but is less than 5% for the uppermost fifth (Figure 3).

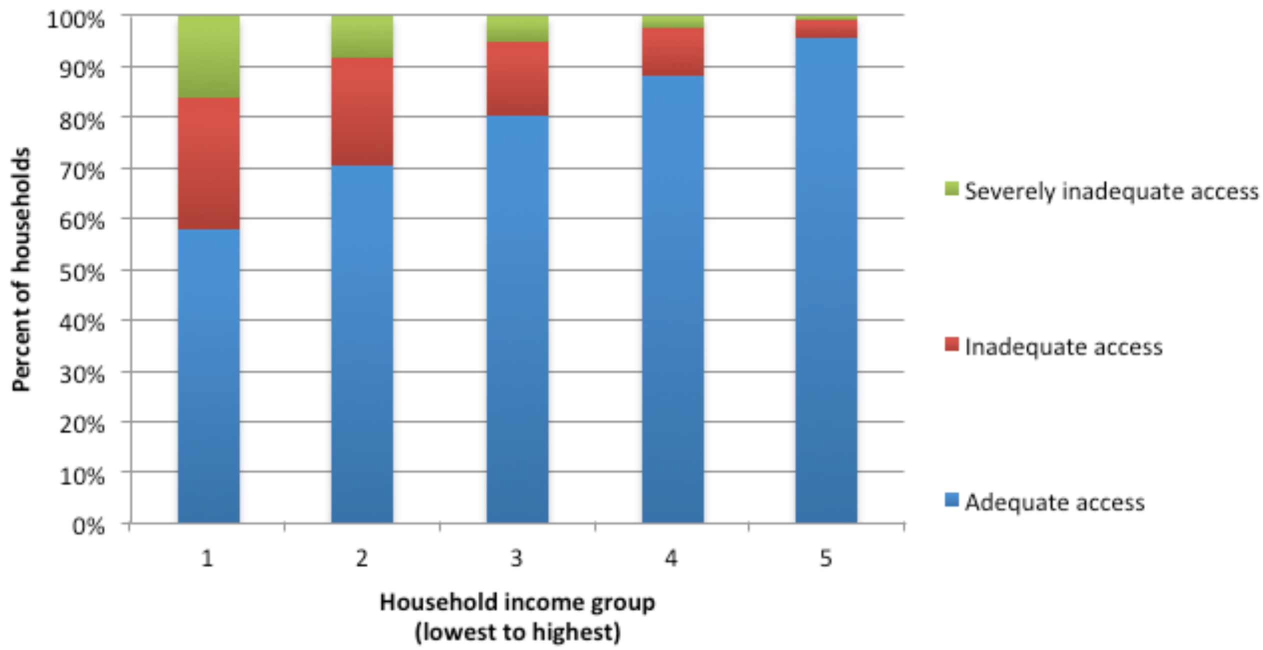
A breakdown of household spending shows a similar pattern, underlining the importance of income in determining food security. On average, food contributes 12.8% of household spending, but this figure is over 30% among the lowest-income groups, and under 10% for the uppermost income groups (StatsSA 2012c). From this data it seems that affordability is a major contributor to food (in)security in South Africa. Food price increases could therefore directly threaten food access security for the lower-income groups. It is also apparent that, in the context of price fluctuations and economic uncertainty, those at risk of hunger do not enjoy the stability dimension of food security.

Figure 2: Food access in South Africa



Source: StatsSA (2013)

Figure 3: Adequacy of household food access by income group, 2011



Source: StatsSA (2012a)

The final dimension of food security under the FAO conceptual framework (FAO 2006) is the capability to effectively utilise food. Cooking energy is widely available in South Africa, either through the steadily expanding electricity grid or as paraffin. An illustrative calculation suggests that energy affordability is unlikely to be a constraint on food security, even among poorer households. Here we use the cooking of four portions of boiled potatoes to represent a reasonable minimum energy requirement for cooking one full meal per day. It is estimated that cooking four portions of boiled potato on a conventional electric hotplate uses 1.2 MJ of electrical energy, or 0.33 kWh (Carlsson-Kanyama and Boström-Carlsson 2001). Cooking one such meal each day would only use about 10 kWh per month, well within the 50 kWh of free basic electricity provided for poor households. Cooking this daily meal using paraffin, even at half the heating efficiency, would require 2 ℓ of paraffin per month, which at the maximum permitted retail price would cost R26. In comparison, 99% of households have total monthly expenditures of over R200 (StatsSA 2013). It therefore seems unlikely that households would go without food as a result of inadequate access to cooking energy.

Although many South Africans lack access to sufficient food, dietary diversity appears to be high. Out of a selection of nine food types, over 40% of households reported consumption from all food groups in the preceding seven days, and only 2.7% reported fewer than five groups (StatsSA 2012a). Eating a diversity of food to ensure nutritional balance does not seem to place a limitation on food security in South Africa.

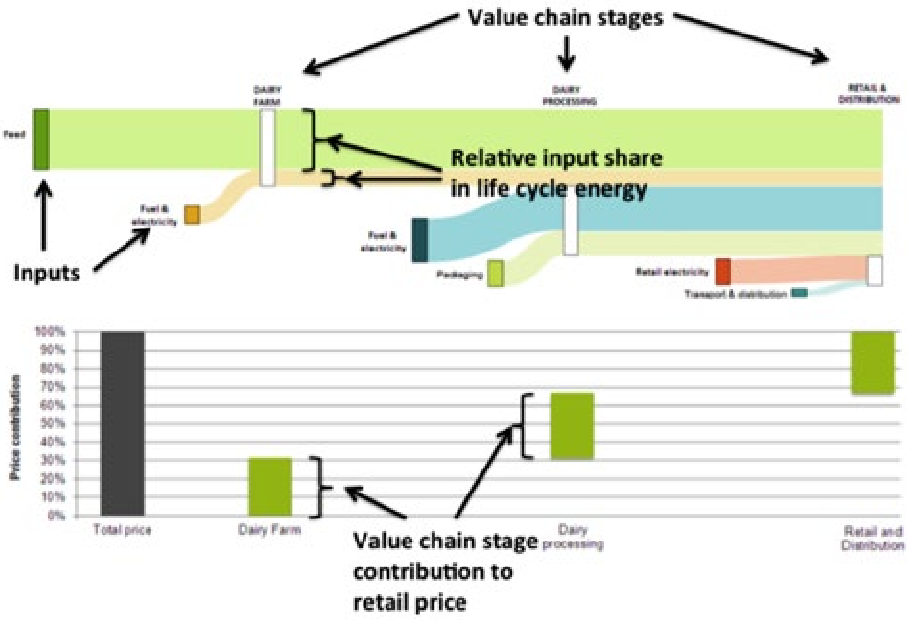
The Bottom Line: Food security is lacking for many households in South Africa, particularly among the poor. This is primarily the result of affordability problems, as there appears to be adequate food available in the country and most households would be able to utilise food if they could access it. Food price increases are therefore likely to directly and significantly reduce food security. The next section considers some examples of the role of energy in food production and supply, and draws together available information on how this could influence food prices.

3. CASE STUDIES

Food production and distribution systems are complex and highly variable and require energy for many different purposes. These systems also need an enormous variety of input materials that require energy for their production, such as agricultural fertiliser and food packaging. Since the process steps and energy requirements vary greatly between food types, and sometimes even for the same foodstuff, this paper looks at a few simplified case study examples to illustrate the role of energy in food provision from a life-cycle perspective. The direct energy use of the food and agriculture industries is considered (electricity and fuel), as well as the energy needed by other industries in order to produce important material inputs like fertiliser and packaging. Where available, information on how the different stages of the value chain contribute to the final retail price has also been collated to explore its relationship to energy. The case-study findings are presented in a standard format that shows the flows of energy as inputs into the value chain at the top, and tracks the contributions to the final retail price at the bottom, where relevant (Figure 4). The plot of price contributions can be viewed as reflecting a farm-gate price, a factory-gate price and a retail price, with the price share of each stage of the value chain represented separately.

The intention of these examples is to illustrate the relative contribution of energy along selected food value chains to inform the discussion presented in section 4, in which the effects of higher energy prices are explored. The examples themselves represent very specific cases and are developed from a number of secondary data sources (details on the development of the case studies and the data sources used are provided in Appendix A). As such, the results are presented in relative terms, as presenting absolute numbers would risk overemphasising their quantitative relevance and precision.

Figure 4: Overview of case study interpretation



Source: StatsSA 2012a

3.1 MAIZE

3.1.1 OVERVIEW OF THE MAIZE VALUE CHAIN

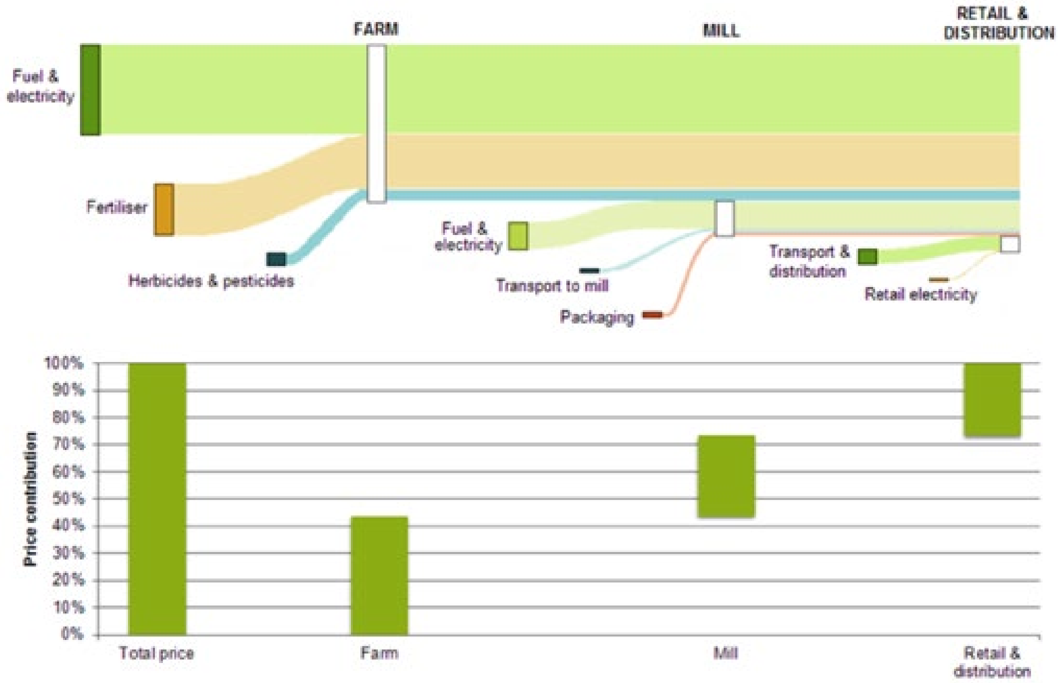
Maize is a major agricultural commodity crop in South Africa, with white maize consumed as a staple food by the majority of the population and yellow maize making up over half of all animal feed produced in SA (DAFF 2012b). Maize farming requires fuel for soil tillage, crop management and harvesting operations, as well as electricity, primarily for pumping irrigation water. Although only 18% of South African maize (by weight) is produced under irrigation (StatsSA 2010), the considerable amount of electricity required for this irrigation still makes a significant contribution to the energy profile of the sector. Maize also requires high fertiliser inputs. Nitrogen fertiliser is the most important from an energy perspective, as the production of ammonia (from which almost all nitrogen fertilisers are derived) consumes large amounts of natural gas and coal.

A highly sophisticated physical and financial infrastructure exists for the trading and movement of commodity grains from farmer to consumer. Here we consider a simplified description that highlights the most important elements from an energy perspective (Figure 5). After the farm, maize requires extensive milling to produce the refined maize meals demanded by the South African market. Besides the energy required for transport from farm to mill, the milling process itself is energy intensive. After milling and packaging, the maize meal is transported to retail outlets, where electricity consumption such as lighting and air-conditioning make a minor contribution to the total value chain energy.

3.1.2 ENERGY USE AND PRICE DEVELOPMENT ALONG THE MAIZE VALUE CHAIN

Figure 5 shows the contribution of each value chain stage to the overall energy required for production, transport and retail of a kilogram of maize meal. It is clear that the dominant energy consumption occurs before the mill, primarily from the production of fertiliser and on-farm energy use. It is interesting to note that this pattern is not reflected in the relative contribution to retail price (lower plot), which shows that less than half of the retail price is paid to the farmer even though the bulk of energy has been used in this component of the value chain.

Figure 5: Life-cycle energy use and contribution to retail price in the maize value chain



Source: References: Appendix A.1

3.2 POTATOES

3.2.1 OVERVIEW OF THE POTATO VALUE CHAIN

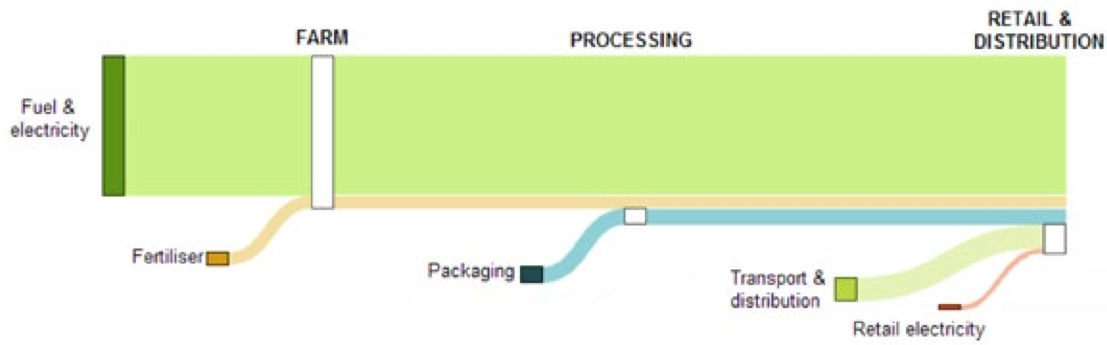
Potatoes make up 61% of the value of vegetable production in South Africa. Potato farms use energy for ploughing and harvesting, and electricity for pumping water, with 75% of South Africa's potato fields being under irrigation (DAFF 2012c). Farmers also apply nitrogen fertilisers that are produced in energy-intensive processes.

After harvesting, potatoes are subject to relatively little processing, although packaging materials carry energy implications from their production stages (Figure 6). However, a potentially significant and highly variable factor is the duration and type of storage. Different potato crops are planted at different times depending on the season and the intended storage and retail times. Potatoes can be sold fresh or stored for several months, either with or without refrigeration (Woods et al. 2010). In South Africa potatoes are produced across the country under a variety of climatic conditions, so fresh potatoes are available year-round (DAFF 2012c). This case study has therefore considered potatoes that are retailed directly after harvest without extended storage, which also offers a useful comparison with the refrigerated-apple case study to follow.

3.2.2 ENERGY USE ALONG THE POTATO VALUE CHAIN

Figure 6 presents the major energy flows in the potato value chain. As was seen for maize, the bulk of the energy inputs occur before the farm gate. On-farm energy makes a much larger relative contribution to potato production than maize on a per-kilogram basis, which can be explained by the greater requirement for traction energy in ploughing and harvesting, extensive use of irrigation, and the high water content of potatoes that reduces their fertiliser requirement on a per-tonne basis. Data was not available to establish the price development across the value chain, but potato farmers receive, on average, a 25% value share in the retail price (NAMC 2012).

Figure 6: Life-cycle energy use in the potato value chain



3.3 APPLES

3.3.1 OVERVIEW OF THE APPLE VALUE CHAIN

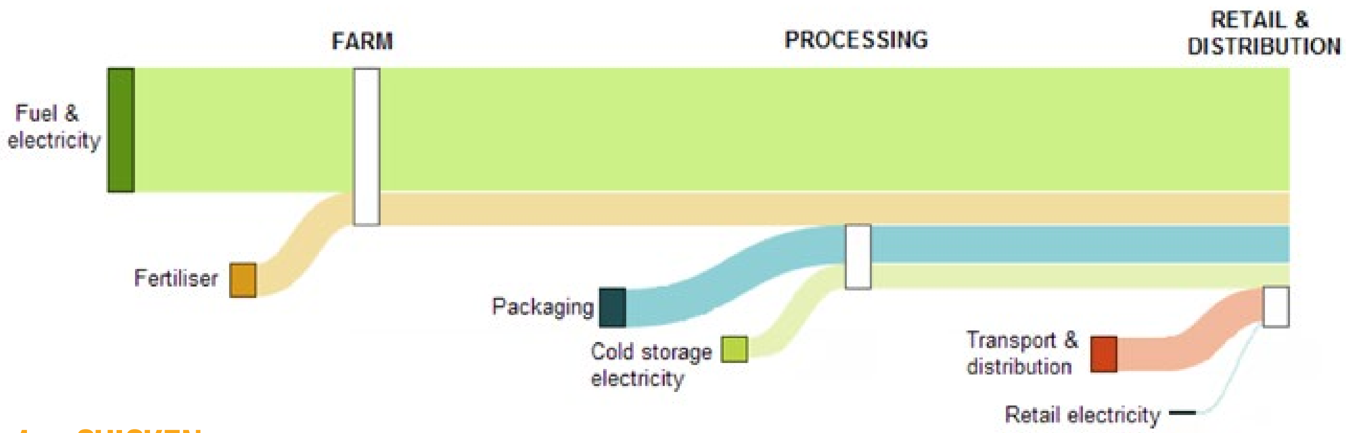
Apples are one of South Africa's most important deciduous fruits and a major agricultural export crop (NAMC 2012). On-farm energy use is rather different to that of field crops, with less fuel being required in tillage, sowing and harvesting, although fuel is still required for orchard management (e.g. planting, pruning) and harvesting (Strapatsa et al. 2006). New apple orchards also take several years to produce fruit, during which time they still require management and add to a farm's energy requirements. Apples are typically grown under irrigation (Agri Benchmark 2013).

Apple harvesting is seasonal, but apples are stored under refrigeration for extended periods to provide a year-round supply to the domestic market (DAFF 2012d). This case study considers apples that are stored for two months before refrigerated transport to retail, where they are placed on display without refrigeration. Naturally this scenario hides a great deal of variability in the life cycle, but nevertheless provides a useful indication of energy use.

3.3.2 ENERGY USE ALONG THE APPLE VALUE CHAIN

The energy profile of the apple value chain is broadly similar to that of the other crops discussed above, but with a distinctively higher energy contribution from later stages. This is primarily due to the energy implications of extended cold storage and the cold chain requirements of transport and distribution. Packaging also makes a relatively larger contribution to apples than to potatoes or maize.

Figure 7: Life-cycle energy use in the apple value chain



3.4 CHICKEN

3.4.1 OVERVIEW OF THE CHICKEN VALUE CHAIN

Chicken is the largest segment of the South African meat market, with 979 million birds slaughtered in 2011, amounting to 1.4 million tonnes of chicken. A further 0.2 million tonnes were imported (DAFF 2012e). The “farm” stage of the chicken value chain depicted in Figure 8 is an intensive grow-out facility, which receives day-old chicks from a hatchery and houses and feeds them for a period of about 42 days, at which time they are ready for slaughter (NDA n.d.). Grow-out facilities use energy for ventilation, temperature control and lighting, among other purposes.

This case study considers the supply of an oven-ready whole bird, cling-wrapped in a polystyrene tray. The relevant processing stages include slaughtering, cleaning and packaging the carcass. A continuous cold chain operates between the processing facility and the retail outlet, including refrigerated display.

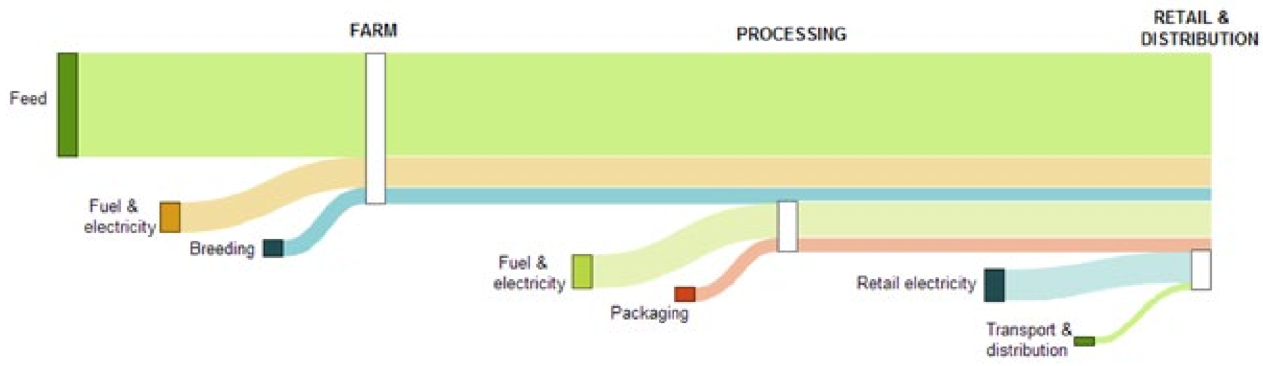
3.4.2 ENERGY USE AND COST ALONG THE CHICKEN VALUE CHAIN

As reflected in Figure 8, feed is a major energy component in the chicken value chain. Chicken feed typically has a maize content of over 50% (Roosendal n.d.), so an indication of the energy breakdown of the feed supply can be inferred from the maize farm inputs shown in Figure 5 above (other major feed components are agricultural crops such as soya and sunflower seed).

The requirement for in-store refrigeration is clearly evident in the retail electricity component. It is important to again point out that these energy diagrams only provide relative comparisons across the value chain in question. Here the apparently much smaller energy requirement for chicken transport and distribution actually represents the same energy requirement as for apples, but the large amount of energy represented by feed has shrunk its relative contribution to the total.

Data limitations again prevent a comprehensive view of cost development across the value chain, but some information is available. The poultry farm receives a 62% share of the retail price of chicken (NAMC 2012), and feed costs account for approximately 70% of total farm costs (Louw et al. 2011).

Figure 8: Life-cycle energy use in the chicken value chain



3.5 DAIRY

3.5.1 OVERVIEW OF THE DAIRY VALUE CHAIN

Dairy production is complex and a number of stages in the value chain are energy intensive. Feed for the herd of cows is a major input, which includes purchases of straw, single feed ingredients and formulated feed concentrates. Concentrates are formulated dairy feed rations that, in common with chicken feed, will usually have a large maize component. In addition to purchased feed, many dairy farmers maintain pastures and grow supplementary feed crops on the farm. Direct energy consumption therefore includes some of the irrigation and fuel use in common with crop growing, added to the energy requirements for milking sheds, refrigeration and other needs. Regular calving is necessary for cows to continue producing milk, therefore a dairy herd will usually be renewed by calves born on the farm (Notten and Mason-Jones 2011a).

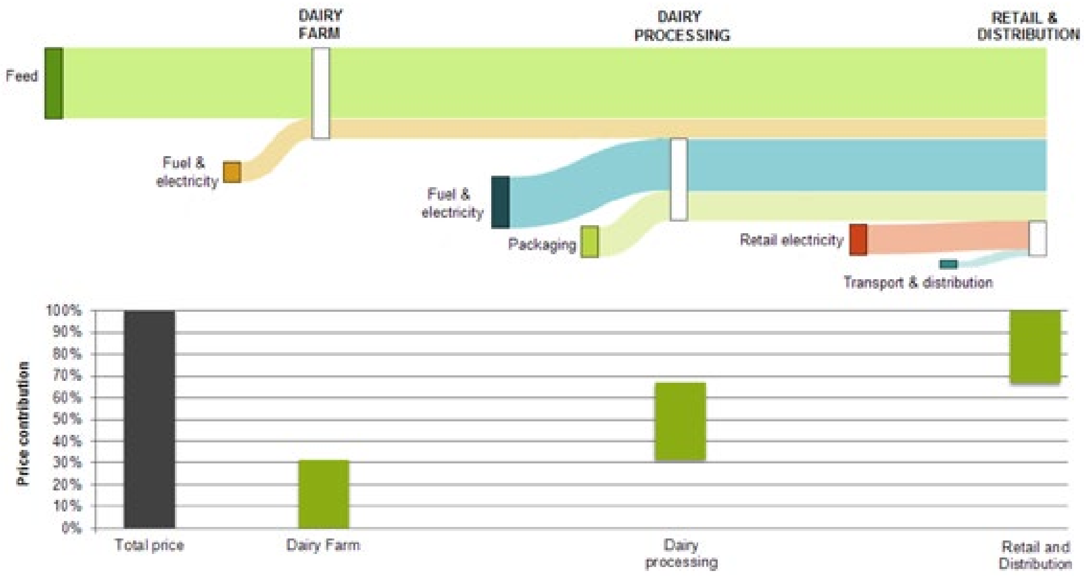
At the dairy, raw milk is processed to yield a wide variety of dairy products. This case study follows the production of one litre of full-cream milk, which involves transport from the farm to a processing facility in a refrigerated tanker, pasteurisation and packaging in plastic bottles, with temperature control maintained throughout. Direct energy use includes steam raising, refrigeration and pumping. From the dairy the packaged milk is transported in refrigerated trucks and placed in refrigerated display units at the retail store.

3.5.2 ENERGY USE AND COST ALONG THE DAIRY VALUE CHAIN

The dairy value chain and its energy implications are presented in Figure 9, which reflects the diversity of energy-dependent processes that contribute to milk supply. As for chicken production, animal feed purchases are the largest life-cycle energy contributor, but because of on-farm pasture and feed cropping and the high energy requirements for processing, it represents a considerably smaller proportion of the total.

The price development shown at the bottom of Figure 9 indicates that the three stages of the value chain receive approximately equal shares of the final retail price. Considering that the retail stage accounts for a relatively small proportion of total energy, a correlation between the energy costs and revenue share among the different players is not evident.

Figure 9: Life-cycle energy use and contribution to retail price in the dairy value chain



Source: References: Appendix A.5

3.6 FISH

3.6.1 OVERVIEW OF THE FISH VALUE CHAIN

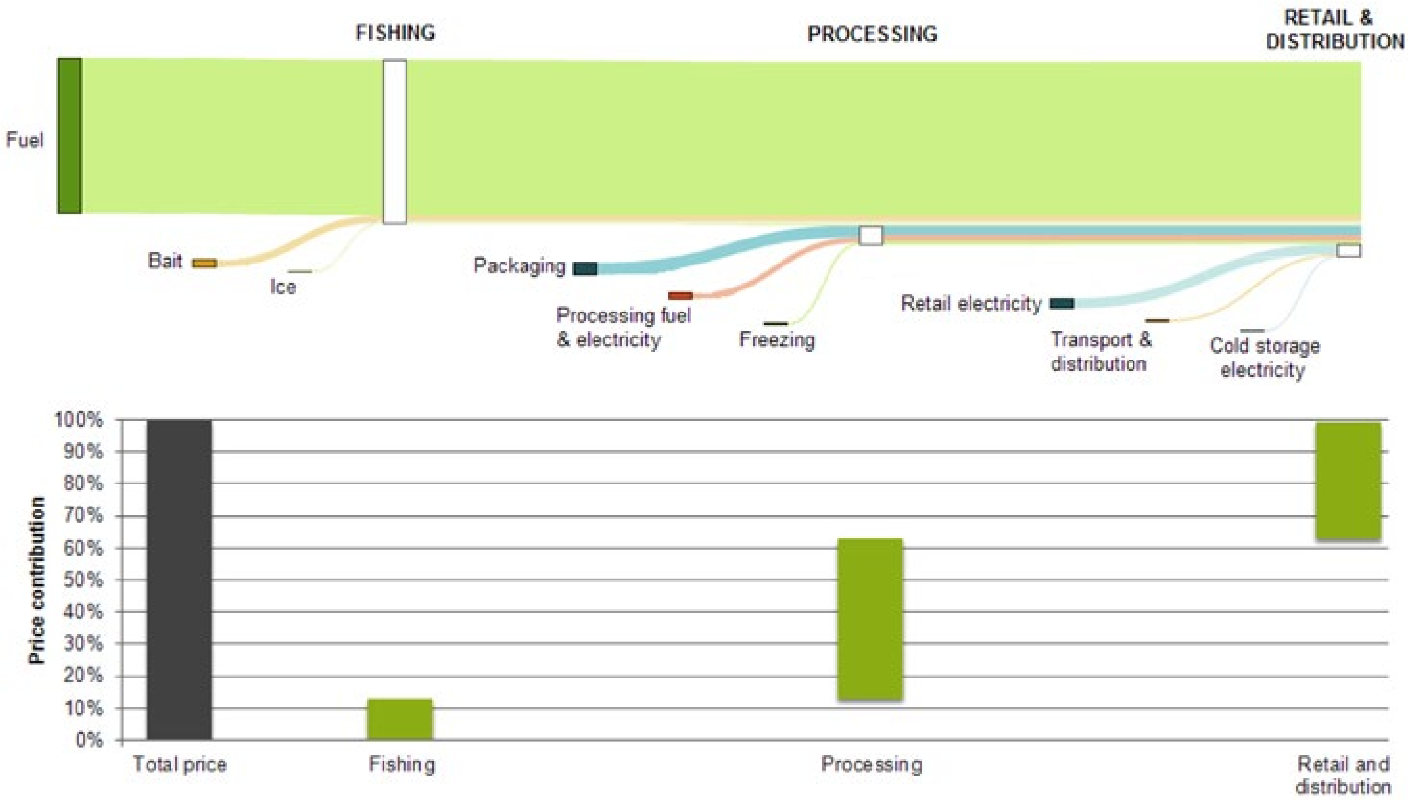
Fish production in South Africa is overwhelmingly from wild marine catches (FAO 2010), so the basis of this food sector is markedly different from the other agriculturally based systems discussed here. Inputs for fishing can include bait and, for smaller vessels, ice for cold storage. However, the most significant input from an energy perspective is the fuel for operating the fishing vessels (Schau et al. 2009). Fuel consumption per catch weight varies dramatically between different target species and fish stocks, fishing techniques, boat configurations, distances and even weather. This makes it difficult to estimate the fuel intensity of fishing without access to detailed local data, but Figure 10 presents indicative values based on the European Union (EU) fishing fleet (Cheilari et al. 2013).

Once landed, fish can undergo a variety of different processes. This case study considers fish that is landed and directly processed to yield fish fillets, which are packaged and frozen. The fillets are kept frozen throughout distribution and retail, with allowance for one month of cold storage in the distribution chain.

3.6.2 ENERGY USE AND COST ALONG THE FISH VALUE CHAIN

It is immediately apparent from Figure 10 that the fuel use of fishing vessels dominates energy use along the value chain, but this should be viewed with an appreciation for the great variability in fuel intensity of fishing fleets. South Africa's industry is dominated by demersal hake trawl fishery and pelagic purse seine fishery for anchovy and sardine (FAO 2010). In the European Union the demersal trawl and seine fleets have fuel intensities ranging from 26 to 80 GJ/tonne landed, while pelagic trawl and seine fleets are lower, at 3 to 26 GJ/tonne landed. The results here represent a middle-range value of 25 GJ/tonne. Despite the great variability and uncertainty, the significance of fuel use is a reasonable conclusion in general terms. Price development across the value chain is shown for the average of the fishing industries in Iceland and Denmark (Gudmundsson et al. 2006), which are assumed to be qualitatively similar to South Africa. This shows that, although the fishing stage consumes the greatest proportion of energy, it holds the smallest share in the final retail price.

Figure 10: Life-cycle energy use and contribution to retail price in the fish value chain



Source: References: Appendix A.5

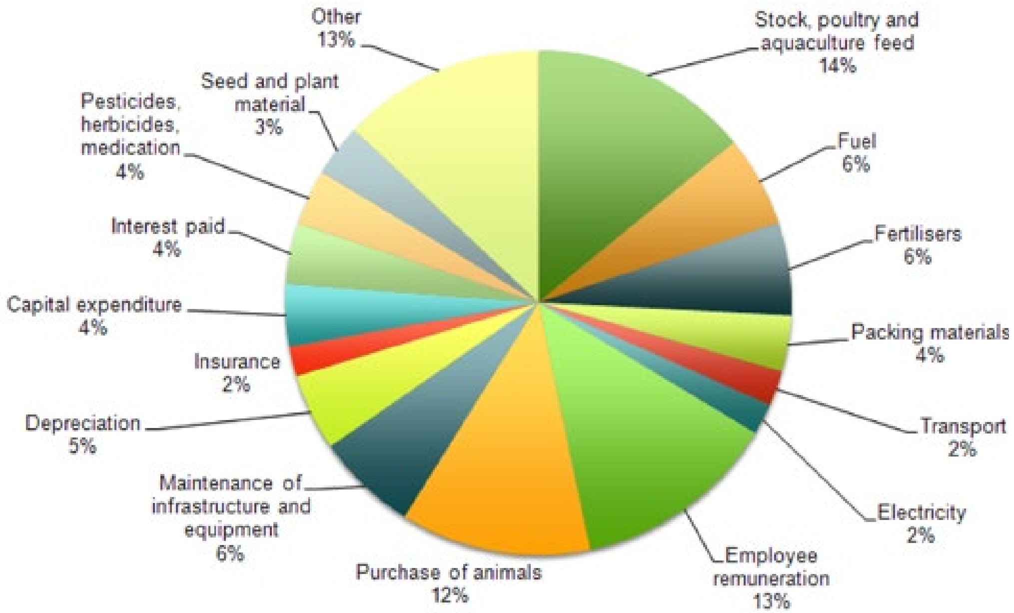
4. THE IMPACTS OF ENERGY PRICES ON FOOD SECURITY

The previous section presented energy and price characteristics of selected food value chains. More general commentary developed from these observations is presented here.

4.1 EFFECTS OF HIGHER ENERGY PRICES

The previous section showed where energy is applied in the value chain of selected food products and, where data allowed, how the final retail price develops over the value chain stages. This assessment indicated that energy requirements are largely (but not entirely) concentrated at the earlier stages, and particularly at the farm level. On the other hand, the contributions of different value-chain stages to the final retail price vary considerably between different foodstuffs, with no evident relation to energy intensity. This reflects the importance of other factors in determining retail prices. Figure 11 shows the cost breakdown of the average South African farm in 2007, with an average 8% share from direct energy (fuel and electricity), and fertiliser contributing 6%. This conceals immense variation between different farming activities, locations and business models, but nevertheless provides a suggestion of the extraordinary variety of cost contributors that are expected to determine the farm-gate price.

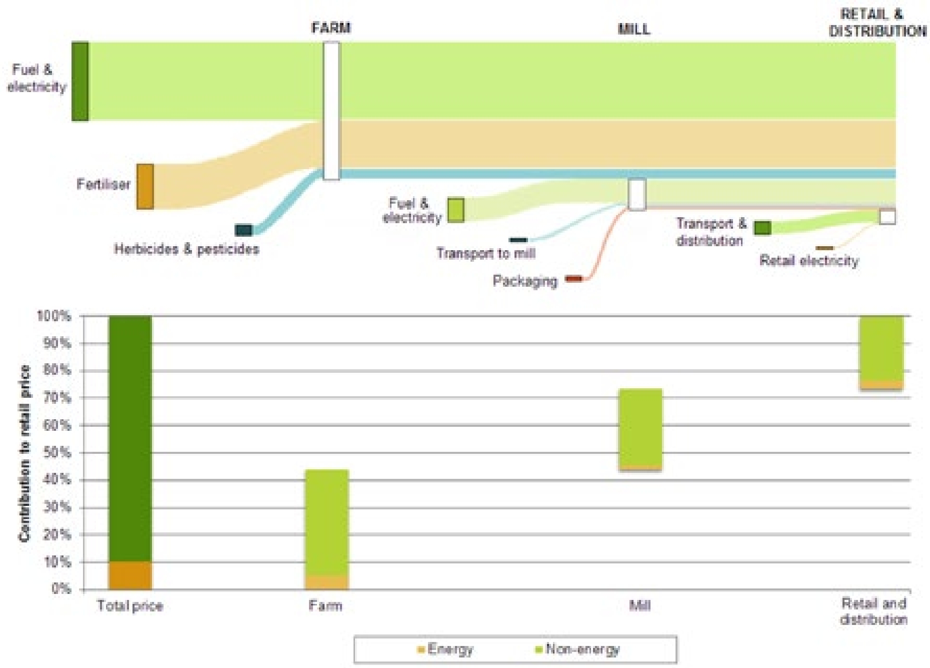
Figure 11: Average cost breakdown of South African farms in 2007



Source: StatsSA (2010)

A rigorous bottom-up analysis of the impact of energy prices on food retail prices would require detailed energy cost data, of the type shown in Figure 11, for each food type and for each stage of production. Such data is rarely available in South Africa. Reconstructing the energy cost share from disparate data sources and indirect calculation is fraught with uncertainty and strong assumptions, but for illustrative purposes this has nevertheless been attempted for maize, in Figure 12, which also reproduces the energy flows from Figure 5 for the sake of clarity. The calculation has taken into account on-farm energy use and the energy cost of nitrogen fertiliser purchases, assuming that 50% of fertiliser expenditure is spent on nitrogen fertiliser, and that the ratio of variable to total farm costs for maize farming is equal to the national average. It takes into account heat and electricity cost at the mill, with plausible energy prices assumed, and includes an assumed 300 km journey, from mill to retail, on a typical freight vehicle at average freight cost.
It therefore captures the four largest energy flows in the value chain, which collectively make up 90% of the life-cycle energy of maize. Data sources used in the calculation are detailed in Appendix A.

Figure 12: Energy share contribution to retail price in the maize value chain



Source: References: Appendix A.1

Notwithstanding the limitations of the approach, Figure 12 provides a number of interesting observations. First, it is clear that energy is a significant but not dominant contributor to the retail price of maize. It is also interesting that the cost shares of energy at the different value stages are not related to the absolute amounts of energy they consume. In the case of maize, about three-quarters (76%) of life-cycle energy has been consumed before the maize leaves the farm gate. However, farm energy use only contributes around 12% to total farm costs (Figure 11), and the farm-gate price makes up less than half (44%) of the retail price. In other words, the cost of on-farm energy use is diluted by the other on-farm costs, and then further diluted by the mark-ups of subsequent value chain stages, so that on-farm energy use contributes only 5% (i.e. 12% x 44%) to the ultimate retail price, despite representing the bulk of life-cycle energy use.

It is interesting to note that the form of energy also has a significant influence. The transport energy reflected under retail and distribution is a minor proportion of overall energy use, but it makes a similar contribution to total price as the much larger amount of energy consumed before the farm gate. This is a reflection of the higher cost of diesel fuel for transport (the main energy form at this stage) compared to farm electricity and coal, or natural gas for fertiliser manufacture.

The complexities of cost composition are overlaid by the influence of market dynamics on prices. In the context of South Africa's open economy, the influence of international fertiliser and commodity crop markets deserve particular mention. In the case of maize, farmers can choose between selling on the local market or on foreign markets. If the international price (inclusive of export costs) is higher than the local price, farmers will export. Conversely, millers have the option to import cheaper foreign grain if local farmers are unwilling to sell at competitive prices. The export parity price and the import parity price therefore tend to set maximum and minimum bounds on the local price (DAFF 2006), although this price range is quite wide: R1 695/tonne (export parity) to R3 002/tonne (import parity) for white maize at the end of 2011 (NAMC 2012). Similar influences can be expected in other markets for commodity crops and, importantly, for fertiliser. This suggests that there is a limit to which local energy prices will influence food prices at the commodity level. Beyond this limit, higher local energy prices will translate into an increase in imports to substitute local production of food or fertiliser (with other non-price implications). On the other hand, low local energy prices in the context of high international energy prices will not contain prices beyond these limits, but will instead lead to greater exports of local production with higher returns to producers.

The influence of energy prices along the value chain (for each different energy source) interacts dynamically with local and international markets, other non-energy cost factors (labour, rent, taxes), interest rates, substitutions between crops, fluctuating crop yields, energy efficiency improvements and many other influences. Beyond these seemingly quantifiable influences, a variety of more qualitative factors also play an important role in price determination, such as the negotiating power of different players and consumer preferences. All of these contribute to a highly complex and dynamic relationship between the price of any single production input, such as energy, and the final retail price.

The disconnection between energy consumption and cost across the value chain suggests a reconsideration of the cooking energy in terms of food security. In section 2, four portions of boiled potatoes were used to represent the minimum daily cooking energy requirements for a household, to allow for one full meal per day. If, for the purposes of illustration, we assume that cooking a kilogram of maize meal requires a similar amount of energy, then at the maximum permitted paraffin retail price, cooking energy adds additional cost in the order of about 20% of the maize meal price, a contribution similar to that of the energy in the maize meal supply. This suggests that, in at least some cases, the energy price impact on the direct energy costs of food preparation could be at least as significant as the indirect costs passed on through the food price.

It is clear that the translation of energy cost along the supply chain is not straightforward and an energy price increase should not be expected to induce a proportional increase in food prices. This is evident from the energy and cost shares across the value chains of the case-study examples, even without considering the plethora of further complications such as international markets, exchange rates, price negotiation dynamics in the supply chain or anticompetitive pricing practices. The effect of an energy price increase on food prices – and thereby on food security – is highly dependent on where energy is used, what share of cost it represents, what proportion of retail price it commands and whether this price can be passed on to the buyer.

4.2 RISKS OF HIGHER ENERGY PRICES IMPACTING FOOD SECURITY

Food affordability is the main obstacle to food security in South Africa, and the preceding discussion has untangled some of the complexities in the relationship between energy costs and food prices. Reliably predicting the effect of an energy price increase on food security was not feasible at this level of analysis, or with the available data, but it was evident that life-cycle energy requirements are often more heavily weighted toward early production stages (at the farm or fishing vessel) than later stages (processing and retail), while the later stages typically contributed a large proportion to the final retail price for those commodities for which data was available. The implication is that for some foods, especially those not heavily processed or refrigerated, a fairly large energy price increase might only translate to a limited price increase at the retail level. This does not necessarily contradict earlier findings that a close relationship exists at the commodity-market level, as commodity crop prices are closely related to farm-gate prices. Instead, by taking the view that retail prices are most relevant to food security, this paper has found that the farm-gate or commodity prices are not always the main component of the retail price and that the direct impact of energy price increases on food security is dampened by the other cost components along the value chain.

These observations should not be taken to mean that energy prices have no short-term impact on food security. The illustrative example of maize still found that energy contributes almost 20% to the final price, so a large energy price increase of the order seen in electricity prices (Figure 1) would still be expected to markedly drive up the retail price. Furthermore, these generalisations are clearly not universal: chicken farming receives a relatively large proportion (62%) of the retail price, and energy use is relatively evenly spread across the dairy value chain.

Insofar as energy price increases do lead to retail food price rises, it has also been indicated that the increased energy-related cost of cooking could represent a burden of similar magnitude to the consumer, with this extra expenditure likely to place further pressure on food affordability for the poor.

Irrespective of the implications of energy price increases for the consumer, the agricultural and fisheries sectors will be impacted upon more directly. This could pose a risk to food security in the long term. If South African farmers face local energy price increases that are not matched internationally, their reduced profitability and competitiveness could deter investment in the agricultural sector and ultimately result in a decline in domestic production, risking shortfalls of food availability in the future. This would also reduce employment in the sector, endanger incomes and further impact on food security.

4.3 ROLE-PLAYERS AND POTENTIAL RESPONSES

A great many stakeholders play some part in the South African food system. Those in the private sector are largely responsive to profit incentives, and energy price increases would induce them to improve their energy efficiency up to a point, after which they would need to pass the cost on to their customers or face declining profitability.

A wide range of governmental entities could potentially play a role in managing the impacts of energy prices:

- The Department of Trade and Industry determines import tariffs that, although constrained by numerous trade agreements, could help to support farmers and protect poor consumers.
- The Department of Agriculture, Forestry and Fisheries naturally has many roles in the sector. One of these is the management of agricultural extension services because a strong extension service could help farmers to make their operations more efficient and manage the impact of energy price increases.
- The Competition Commission is important – it ensures that pricing is competitive throughout the value chain, so that neither farmers nor consumers are subjected to unfair pricing practices by larger players.
- NERSA, the national energy regulator, determines various energy prices in South Africa.
- The South African Reserve Bank determines monetary policy, with a very wide range of implications. These affect inflation, which is explicitly targeted for a desired range (SARB n.d.), and exchange rates, both of which are important determinants of farm costs for food prices.
- The Department of Social Development is responsible for South Africa's social welfare system, which is administered through the South African Social Security Agency.

The complexity of the food system's cost components calls for more detailed analysis before clear-cut recommendations can be made. Nevertheless, some tentative perspectives can be set out here. From a food-security perspective, the concerns are twofold. First, the affordability of food needs to be maintained and improved. Secondly, the long-term viability and competitiveness of the agricultural sector needs to be assured.

Interventions that focus on energy prices in an attempt to contain food inflation would appear to be relatively indirect in their effects. Their influence on the retail prices would be diluted by other cost components and can potentially be undermined by interactions with international markets. Since the consumers in the lower income groups are the intended beneficiaries of such an action, more direct support might be more appropriate. This is the essence of social security grants, for example, which appear to have positive effects on household food security (StatsSA 2012a). The direct energy costs to households also need to be considered, as these could prove to be as significant as the effects transmitted through the retail pricing of food. This suggests that mechanisms such as the free basic electricity policy play an indirect but nevertheless targeted role in supporting food-insecure households.

Limiting energy price increases would benefit farmers more directly. This would enable them to keep their costs down and help them to remain internationally competitive. However, even in this case it must be noted that energy is one among many costs and not necessarily the best mechanism by which to support agricultural competitiveness. For example, low domestic energy prices in the context of high international prices could fail to contain the prices of fertiliser or animal feed available to local farmers, because these inputs are traded on international commodity markets.

This paper has taken a highly cost-focused approach but it is expected that many other factors play an important role in food pricing and its effect on food security. Further research is needed to gain a more complete understanding of energy costs at each stage of the value chain and their role in determining retail food prices. This should be coupled with a more comprehensive investigation of the economics of food production and supply in South Africa.

5. CONCLUSION

Available data for South Africa shows that large numbers of people suffer from food insecurity. This is primarily a problem of food affordability. There is sufficient food available to provide nutrition for the population, and the vast majority of people would be able to utilise food if they could afford to purchase it.

In this paper, energy and cost contributors have been examined along the value chains of a selection of foodstuffs. It has been shown that the translation of energy cost along the supply chain is not straightforward, and an energy price increase should not be expected to induce a proportional increase in food prices. The complexity prevents a reliable prediction of how food prices would respond to an energy price increase, and the responses are likely to vary between food types. Although energy price increases would influence food prices, in some cases they would translate to a limited price increase at the retail level, due to the many other cost factors along the value chain.

Increased energy costs would be more directly felt by farmers and fisheries. This could pose a long-term food-security risk if reduced profits deterred investment in the sector, with a resultant decline in production. Although restricting energy price increases might have a role to play in protecting food security, the findings of this paper have suggested that, in the short term, this would be a relatively indirect approach. More direct mechanisms to protect poor customers might be more effective, for example by extending social security grants and free basic energy subsidies. Farmers and fisheries would benefit more directly from lower energy prices, with long-term benefits to production levels, but these sectors also involve many other cost components that could be targeted to compensate for energy prices increases. There are therefore many possible approaches to combating the negative impacts of energy price increases at the agricultural and fisheries level.

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APPENDIX A: DATA SOURCES AND METHODOLOGY

This Appendix provides a description of the data sources, assumptions and calculation methodology used to derive the energy and cost contribution results that were presented in the paper. In general terms, the calculations were based on a review of life-cycle assessment literature, where assessments of energy use for the particular products have been previously reported. However, in many cases these results required some conversion to ensure that they were comparable between different products, and often several studies were consulted to develop a full picture of the supply chain.

A.1. MAIZE

Maize farm energy use was available from South African data collected as part of previous life-cycle assessment (LCA) research (Notten and Mason-Jones 2011), which included energy used in the manufacture of agrochemicals. As LCA data for maize milling was not available, it was assumed that energy intensity per unit output was similar to that for flour milling, with energy consumption data taken from a European LCA database (Nielsen et al. 2003). Transport was incorporated using a fuel intensity of 22 tkm/ℓ and typical diesel characteristics (Braun 2008; DEFRA 2013), assuming a journey of 50 km from farm to mill, and 300 km from mill to retail outlet. Cumulative energy demand of packaging was based on LCA database values for typical packaging board and an assumed packaging mass of 5 g per 2 kg of maize meal (ecoInvent 2013). Retail energy use was estimated on the basis of non-refrigerated retail energy use per square metre of retailing space (475 $MJ/m^2.y$), determined from a previous study in South Africa (Notten and Mason-Jones 2011), and based on a stocking rate of 200 kg of maize meal per stat metre and a shelf turnover of 10 days.

The overall cost calculations for maize relied on a breakdown of price development along the value chain provided by the National Agricultural Marketing Council (NAMC 2012), which compared the maize price at various stages of the value chain. These were normalised to a retail mass basis.

The energy cost breakdown for maize presented in section 4.1 of the report disaggregated the energy cost components from the overall cost by estimating energy costs at each value chain stage. Paucity of data necessitated the use of generic farm data from StatsSA's agricultural census (StatsSA 2010), which was used to estimate the ratio of variable cost to total farm costs (excluding animal-related costs). An indicative value of fertiliser's share of maize farm variable costs was available, at 40% (Grain SA 2011) which, together with the StatsSA data, was used to calculate a share of total farm costs. Only nitrogen fertilisers were considered, as these are the most energy-intensive macronutrient fertilisers, and it was assumed that half of all fertiliser expenditure was for nitrogen. Fuel and electricity spending was aggregated as a percentage of total costs, also from StatsSA (2010). Energy used in the production of herbicides and pesticides was omitted, as it is a minor energy contributor, with limited data to support a confident quantification.

Energy costs at the milling stage were only estimated for fuel and electricity, using requirements for milling from a food LCA database (Nielsen et al. 2003), assumed electricity prices of 40c/kWh and a heat price at half this level (6c/MJ).

Only transport, the dominant component of retail energy use, was considered for the retail stage. This was estimated from typical truck and fuel characteristics and performance (Braun 2008; DEFRA 2013), an assumed 300 km travel distance from mill to retail outlet, and the average wholesale diesel price for 2012 (AA 2013).

A.2. POTATOES

Farm energy use was calculated using an energy productivity value of 879 g/MJ for South African farms (Franke et al. 2011) and an international estimate of 28% diesel share in total energy use (Williams et al. 2006). This allowed electricity use to be disaggregated and converted from electrical energy to primary energy using Eskom's efficiency of generation, calculated from data in their annual report (Eskom 2013). Fertiliser inputs for South African potato farms were taken as 170 kg N/ha (FAO 2005). This was converted to a life-cycle energy consumption using ecoInvent data for urea fertiliser (ecoInvent 2013) and converted to a kilogram of potato basis using South African yield data of 42.5 tonne/ha (Franke et al. 2011).

Energy of packaging manufacture was calculated using packaging characteristics from Potatoes South Africa (2013) and life-cycle energy use for paperboard manufacture (ecoInvent 2013).

Energy involved in transport to retail was calculated as for maize. Retail electricity use was similarly calculated, except with an assumption of retail display stocking at a rate of 100 kg/m^2 and a five-day shelf turnover. As noted in the text, the energy profile was calculated for potatoes that are not refrigerated or stored for significant periods.

A.3. APPLES

On-farm energy use data was taken from Fadavi et al. (2011), which included primary energy-use data for apple farming in Iran. No South African farm data was identified. Nitrogen fertiliser application rates, yield and manufacturing energy were taken from Strapatsa et al. (2006).

Energy implications of packaging were taken from Blanke and Burdick (2005). Cold-storage energy was calculated to account for initial cooling as well as a cold-storage period of 60 days, using energy intensity data from Milà i Canals et al. (2007). Transport and distribution was assumed to have the same energy requirement as for potatoes, but assuming a 25% increase in fuel use due to refrigeration, as determined in a previous study (Notten and Mason-Jones 2011). Retail energy was calculated assuming non-refrigerated display, with the same energy intensity per square metre as for maize and potatoes (475 $MJ/m^2.y$) but with an assumed stocking rate of 100 kg/m^2 and a shelf turnover of three days.

A.4. CHICKEN

Energy use involved in breeding, feed production and on-farm fuel and electricity use in chicken production was taken as the average for two Australian regions to give values of 1.55 MJ/kg, 9.75 MJ/kg and 2.85 MJ/kg respectively (Wiedemann et al. 2012).

The same source also provided the energy use for processing (Wiedemann et al. 2012), while packaging life-cycle energy was calculated on the basis of energy requirements (ecoInvent 2013) for a 20 g polystyrene tray with 3 g of plastic stretch-wrap, carrying a 1.6 kg oven-ready chicken.

Refrigerated transport, distribution and retail display were assumed to be the same (on a per-kilogram basis) as for fresh milk (Notten and Mason-Jones 2011).

A.5. DAIRY

Life-cycle energy use along the dairy value chain was available from a previous South African study (Notten and Mason-Jones 2011; Notten and Mason-Jones 2011b).

A detailed breakdown of the price composition along the milk value chain was available from the NAMC (2012). This was slightly adjusted to ensure that all distribution functions were attributed to the retail value chain stage, to be consistent with the other commodity calculations.

A.6. FISH

Diesel use in fishing was taken from a study of the EU fishing fleet (Cheilari, et al.2013) which reported an average diesel consumption of 728 ℓ/tonne round weight. A round-to-fillet weight conversion (1.82 kg round/kg fillet) was derived from other sources (Vázquez-Rowe et al. 2011; Schau et al. 2009). A conversion to megajoules was based on typical diesel characteristics (IPCC 2006; SAPIA 2008).

Bait requirements were taken from Svanes, et al. (2011), but assumed to be on a kilogram-to-kilogram basis. Energy requirements for bait production were taken to consist of only diesel fuel, at the same rate as calculated for saleable fish.

Energy required for land-based ice production (0.043 MJ/kg round weight) was taken from Schau et al. (2009). Since only smaller boats purchase ice for cooling at sea, it was assumed that only 30% of the catch would be ice-cooled.

Packaging material types and masses were taken from Vázquez-Rowe et al. (2013), based on the packaging for a box containing 320 g of frozen fish fingers. Life-cycle energy intensity of the materials was obtained from the ecoInvent LCA database (ecoInvent 2013). Electricity use in processing was calculated from a value of 0.36 kWh/kg processed (Svanes et al. 2011), and the energy required for post-processing freezing was taken into account (Vázquez-Rowe et al. 2013).

Cold storage for a period of one month was calculated from the energy-use data in Vázquez-Rowe et al. (2013), but with the storage period reduced from nine months to one month since this data source considered highly processed fish products rather than whole fish fillets for which freshness would be a greater priority. Energy implications of refrigerated transport, distribution and retail were assumed to be similar to those for dairy (Notten and Mason-Jones 2011).

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