FOOD REFRIGERATION: WHAT IS THE CONTRIBUTION TO GREENHOUSE GAS EMISSIONS AND HOW MIGHT EMISSIONS BE REDUCED?

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SUMMARY

Today's food system is built upon refrigeration. For many foods, refrigeration is a feature of almost every stage in the supply chain. This paper looks at what this means in terms of refrigeration's contribution to UK greenhouse gas (GHG) emissions, at how this reliance on refrigeration has come about and what the consequences might be as regards future trends and associated emissions. It looks at how we might be able to reduce greenhouse gas emissions associated with food refrigeration both by improving the greenhouse gas efficiency of the equipment itself and, as a culture, by reducing our dependence on the cold chain.

Refrigeration creates greenhouse gases both because of the energy used to operate the equipment and because of the inherent global warming potential (GWP) of the refrigerant gases. It is hard to quantify precisely what contribution refrigeration makes to the UK's greenhouse gas emissions since the number of enterprises that use refrigerated equipment and the size and efficiency of this equipment varies very widely indeed. Roughly speaking we estimate that refrigeration associated with the food that we eat accounts for about 3-3.5% of the UK's greenhouse gas emissions. Figures for the refrigeration at the food manufacturing, retailing and domestic stages are available and total about 2.4% of UK greenhouse gas emissions. An additional half to one percent is added here to take into account the hidden 'embedded' energy of foods (such as meat, fruit and vegetables) that are grown or manufactured abroad and imported, together with the additional energy used by mobile refrigeration units while food is being transported within the UK.

There is, however, much scope for improving the efficiency of refrigeration in the UK. It is generally considered that energy savings of between 20% and 50% are possible through the proper specification, use and maintenance of equipment. Some improvements can be achieved by better maintaining and operating existing equipment; additional savings will be achieved by specifying cleaner and more appropriate equipment to replace older technologies. There is plenty of information and advice available from bodies such as the Carbon Trust, the Institute of Refrigeration and the International Institute for Refrigeration. In essence the four key elements of a more efficient system include minimising the load, minimising the temperature difference, checking the controls and maintaining the system properly.

There are currently various policies and incentives both in the UK and at the EU level that seek to influence energy use. The EU's Energy Using Products (EuP) Directive, still in its initial stages, is developing design requirements to address the environmental effects of energy-using products throughout their life cycle. Products must then meet set criteria in order to be placed on the market. Preparatory studies are currently underway and it is envisaged that for commercial refrigeration technologies, the study will be completed in July of 2007 and adopted by the European Commission in 2008.

Within the UK, the sector has negotiated a Climate Change Agreement (CCA), which commits participants to reducing energy use by between 12% (from a 2005 baseline) by 2011, with – as an intermediary target – a 5% reduction by 2008.

The CCA covers only commercial cold-storage enterprises where the refrigeration element is the main purpose of their business – in other words, where coldness is what is being sold. Businesses where refrigeration is used during the process of selling or producing something else (such as food) are not eligible for a CCA. As such, businesses that are more moderate users of energy have little incentive to improve their energy efficiency. Recognising this, Government is currently considering and

seeking consultation on the merits of a new scheme, the Energy Performance Commitment (EPC).

The EPC aims to cut carbon emissions from large commercial and public sector organisations by 1.2 million tonnes per year by 2020. The intended targets of the EPC are non energy-intensive large organisations that are not included in the EU Emissions Trading Scheme (ETS) or CCAs and which include supermarkets, hospitals, hotel chains, local authorities, and central Government. The Department for Agriculture, Food and Rural Affairs (Defra) calculates that together they account for around 15 MtC of carbon emissions or nearly 10% of the UK's entire economy wide carbon (not GHG) emissions.

Further gains can be achieved through the development and implementation of newer technologies. One particularly promising technology is trigeneration – systems that produce combined heat, power and coolness – and current trials suggest that such technologies are twice as efficient as existing ones. At their cleanest, these systems could even use biomass as a fuel source.

The global warming effect of refrigeration is caused not just by energy required to operate it, but also by the refrigerants used. The latter, for commercial systems, account for about 15% of greenhouse gases emitted. Hydrofluorocarbons, which are currently the standard refrigerant fluid, can have a very high global warming potential; a switch to refrigerants such as hydrocarbons, which have a zero global warming potential can thus lead to overall greenhouse gas reductions provided the refrigeration system has been designed properly and with their use in mind. Further efforts are needed to improve the design of such HFC-free systems. Regulations tightening the use of F-gases (other forms of fluorocarbon refrigerant, also with high global warming potential) will also come into force over the next few years. While the F-gas regulation does not prohibit their use, they place tighter controls on leakage and require business to use only qualified people to carry out associated work.

One of the obstacles to improving energy efficiency is that current business thinking favours short-term gains over longer-term savings both in energy and money.
It can be the case that even when the long-term advantages are quantified and set out, the desire to cut costs in the short term, or to buy a familiar product ('let's go for the same as last time') is overwhelming. Traditional or long-standing industry purchasing relationships also have a part to play – a product is bought from the same supplier time and again because it offers familiarity and predictability. Those responsible for maintaining and servicing the equipment may also have a stake in the continuation of less efficient equipment since this is where their expertise lies. Hence the same, less efficient products continue to be manufactured and used even where better alternatives are readily available.

Collaborative action by the various players in the cold chain – including the manufacturers of the relevant technology, those responsible for servicing it and of course the end users themselves need to work together to break out of this systemic inertia. Another approach that offers potential is for end users to contract out the business of 'coldness' to Energy Service Companies (or ESCOs).

A retailer using an ESCO, for example, would not so much buy refrigeration equipment, as a cooling service. It could specify certain parameters and then leave the ESCO to specify, provide, maintain, monitor and improve on the refrigeration equipment. Since the ESCO, under the terms of its contract, would be picking up the energy bills, it would be in their interests to ensure that both the equipment and the management of that equipment were as efficient as possible.

The commercial sector includes not only those who operate refrigeration equipment but those who retail it to householders. As such they have the ability to 'edit' people's choices – they can simply choose not to stock inefficient appliances. Since all stores in any case need to make decisions as to what to stock and what not to, environmental considerations simply need to be incorporated into these decision-making processes.

Future years are likely to see general improvements in the overall efficiency of the refrigeration stock in the UK, although the level of improvement will depend very much upon the strength of supporting policies. According to projections published by the Government-funded Market Transformation Programme (MTP), overall energy use by commercial refrigeration could rise by 6% or fall by 8% compared with a 2000 baseline, depending on the framing policy context. For domestic refrigeration, energy use is projected to fall whatever the policy scenario although there is a twofold difference between the best and worst cases.

Taking the domestic and commercial projections together, the MTP anticipates an absolute decline in refrigeration-related emissions. Importantly however, the MTP projections do not take into account refrigeration energy used by goods in transport, nor do they look at refrigeration energy used by processing plants overseas. Very importantly, in our view, the MTP projections do not take into account cultural trends and changes in marketing, lifestyle, food innovation and the environment which could substantially alter their conclusions. Cold chain technology is embedded in each life cycle stage of today's food system; its ubiquity means that new food products and technologies emerge that are predicated on refrigeration and as such exacerbate and increase our refrigeration dependence.

How did this refrigeration dependence come about? A look at the history of refrigeration shows that mechanical refrigeration was developed in the first part of the nineteenth century, and by the 1870s had started to be used to import frozen meat into the UK from Australia. The First World War gave impetus to the development of cold storage infrastructure and by the 1950s temperature control started to be used in many parts of the supply chain.

Uptake of domestic cold appliances lagged behind however; the domestic refrigerator entered the mainstream market after the Second World War but even as late as 1970, over 40% of the population still did not have a fridge – only 3% owned a freezer. Today, by contrast, ownership of some kind of fridge-freezer combination is almost universal in the UK. The commercial space devoted to frozen foods is ten times greater than it was less than a hundred years ago, in addition to which there is an unquantified space allocated to chilled foods.

This growth in refrigeration dependence went hand in hand with a number of social and economic developments. One should note that the extent to which these developments helped *engender* and to which they simply *reflected* our dependence upon refrigeration is not always clear, nor indeed is there likely to be a clear-cut distinction between cause and effect.

With the post-war economic boom average per capita incomes increased and more women entered the workforce; this combination meant there was more money to spend and less time to shop for and prepare food. Shopping patterns changed – instead of the daily shop (or daily delivery) people flocked to the rapidly growing supermarket formats for a once-a-week bulk shop. These supermarkets devoted more

and more of their retail space to refrigerated goods, and today refrigeration accounts for about half of total store energy use.

As regards frozen foods; it was the frozen food manufacturers themselves who were key to the development and widespread uptake not just of the frozen foods themselves but also of the technological infrastructure. This in turn produced a snowballing effect; the technology prompted the development of further frozen goods and vice versa.

With the post Second World War building boom, household designs gradually changed; the larder was eliminated and central heating installed. These changes had an impact on the keeping properties of food. With no separate cool space for food storage and with increases in average household temperatures (trends show that temperatures have grown substantially since the 1970s), food left out was more likely to spoil. Hence the refrigerator provided a necessary alternative.

Changing food tastes have had a significant part to play. Although the basic raw ingredients of our diet – meat, dairy products, fruit, vegetables, cereals, fats and sugars – have not changed much since the 1950s, within those food categories we seem to have developed a taste for the more perishable foodstuffs, salads being an example here. We are also choosing to eat many foods in processed form; potatoes, say, which have been processed and then frozen or chilled. Other changes such as the massive increase in consumption of chilled soft and alcoholic drinks in the home have also increased refrigeration dependence. In addition, our definition of which foods need refrigerating may also have expanded.

In future years, our changing, warming climate is also likely to increase demand for refrigeration. Foods such as eggs which today are usually retailed on open shelves may need to be refrigerated in coming years. Moreover, in hot weather our preference for chilled and frozen foods is also likely to grow.

Our reliance on refrigeration is about more than a dependence on cold chain technologies alone. It is part of a dependence on a nexus of transport, packaging, retail and IT infrastructure within which refrigeration technology is situated. How these, and perhaps new technologies and infrastructures interact and develop in future years, and what the environmental implications might be, is impossible to say. It is likely, however, that new developments *will* arise. As such, 'straight' projections of the type undertaken by the MTP, above, while useful, are unlikely to tell the whole story. Given the probability of these new developments, it may well be that in coming years refrigeration dependence will grow.

While refrigeration entails the use of energy it can of course also help save energy by reducing food waste. After all, wasted food represents a waste of all the embedded energy used to produce, process, transport, store and retail it – the extra energy required to preserve the food may outweigh the potential embedded energy losses through spoilage. As a starting point, there is probably a relationship between appropriate refrigeration and less waste given two *identical* sets of purchases and an *identical* period of time before it is eaten. Refrigerated food lasts longer and as such is less likely to go rotten and need to be thrown away. Temperature control along the whole of the supply chain also enables producers (e.g. farmers or hobby gardeners) to manage seasonal gluts that cannot all be eaten in one go. Foods can be frozen and consumption can then be spread over a period of weeks or even months.

However it does not necessarily follow that in the less refrigerator-dependent past, households wasted more food, nor that in a (hypothetical) less refrigerator-dependent

future, waste levels will inevitably increase. As discussed above, the *way* in which food is shopped for and managed affects the need for temperature control. Our attitudes to wasting food and subsequent behaviours are also critical. Food is cheaper now, relatively speaking, than it has ever been before. Research suggests that while the relationship between income and food waste is a complex one there does overall appear to be some correlation. In other words, if one can afford to waste food, then one does, refrigerator or no refrigerator. One might also speculate that the symbolic, even religious import of food has also been eroded – food is now simply another commodity. And while we are certainly full of guilt about food this guilt now centres on bodily aesthetics. We are happy to waste food if it makes us thinner. Hence while refrigeration has the technical capacity to reduce food waste, the changing attitudes and behaviours that have gone hand in hand with the uptake of refrigeration may have had a counterbalancing effect.

Another issue that clearly needs addressing in the context of refrigeration dependency is food safety. No one wants to become ill or die of food poisoning. But is a food system which uses less refrigeration inherently more risky?

As with waste, while the short answer is yes, the long answer may be more nuanced. Temperature control is certainly very important in ensuring our food is safe to eat. However the presence of refrigeration has in turn shaped the development of the sorts of foods we choose to eat, of the way we shop and of the way we cook. Refrigeration is now essential because the foods we now consume and the frequency with which we shop are predicated on refrigeration. In short, refrigeration has made itself indispensable. It is worth noting too that refrigeration has enabled other food safety problems to arise. It has facilitated the development of longer supply chains which themselves have given rise to international incidence of certain forms of food poisoning. Salmonella (in eggs and poultry) and more recently the extremely widespread Sudan Red colouring safety alert are fairly recent examples.

Refrigeration is not always used to preserve the safety of our food; often it is used to preserve its quality. For some foods refrigeration is used, and considered necessary so as to ensure our food conforms to certain quality standards as much as to preserve its safety. The question then arises as to how refrigeration is ‘necessary’ in order to maintain food safety standards and how far it is simply used to preserve food in the condition which we have now come to consider as ‘normal’. The distinction between ‘necessary’ and ‘cosmetic’ refrigeration is of course a difficult and subjective one and will differ between stakeholders.

What then, might a lower refrigeration system look like? And what policies and commercial or institutional practices either exist or could be developed that would foster a shift in this direction?

It is important here to delineate the distinction between reducing refrigeration energy *use* and reducing refrigeration *dependence*. The former entails the use of cleaner and alternative technologies and better management practices to reduce energy requirements for a given quantity of food storage. Some of these have already been discussed. The latter, on the other hand, requires changes in our way of living and consuming so that there is less need to store food under refrigerated conditions.

One way of reducing dependence is by changing the balance of foods we eat. Less reliance on meat and dairy products would be an important start here since these tend to be the foods that are most critically dependent on refrigeration. Importantly, livestock production is in any case a highly greenhouse gas intensive process, accounting for the largest share of food emissions by food category. Hence a

reduction in our production and consumption of these foods will not just reduce refrigeration needs but could lead to far more substantial overall savings in GHG emissions. Given the centrality of livestock farming to the rural economy and culture this is a highly problematic issue but it nevertheless needs to be addressed.

As regards fruit and vegetables, a shift towards the consumption of more seasonal and more 'robust' (i.e. less perishable) produce could also lower emissions since it would reduce reliance on refrigerated imports. Robust produce tends to be less critically refrigeration (and packaging) dependent. At present however, most Government policy concerning fruit and vegetables is largely concerned, for health reasons, with getting us to eat more of them. There is little focus on the environmental implications of producing or consuming different types of fresh produce. Indeed, notwithstanding Government's sustainable food and farming strategy we have yet to see any explicit Government analysis of the relationships and tensions that exist between agricultural development, dietary health and environmental wellbeing either for fresh produce or for any other foods.

Finally, if we are to reduce our dependence on refrigeration we may have to accept 'good enough' quality food; food which is perfectly safe to eat but which may, for example, be softer in texture (as for some fruits) or blemished. This of course flies in the face of current retailing practices and so far there are no signs that Government is even considering this issue.

A less refrigeration dependent system might be one where we shop more frequently for food. More regular trips to the shops, provided they are on foot, can make it possible for people to have smaller fridges. It is possible, however, that a shift by the public to daily shopping patterns could have an effect on retailers' delivery systems – they may need to deliver lower volumes more frequently in smaller and less efficient vehicles. However since the total volume of foods the public purchases over the course of a week is unlikely to change, this is by no means certain. This is an issue that needs to be looked at more closely since from a transport emissions perspective too, a shift away from car-based shopping is desirable.

A shift towards a less refrigeration-dependent food system cannot be undertaken in isolation from other moves towards reducing energy dependence in all other aspects of life. As such it is worth highlighting one possible policy approach which is currently being examined, the Personal Carbon Allowance (PCA) or Domestic Tradeable Quota (DTQ) is currently being considered by Government. The concept is based on a 'cap and trade' system in which an overall sustainable allocation of carbon is divided up equally among the population. The carbon credits are 'spent' when individuals purchase energy in one form or another. At its most simple it would be linked to transport fuel and domestic energy use and as such would have a direct influence on people's use of refrigeration-related energy use. People using less than their share of carbon could sell the surplus on the carbon market to people or businesses using more than their allotted share. In time the scheme might be extendable to the purchase of goods (such as food) which have an embedded carbon footprint although it could well be more feasible for emissions during the production of the foods themselves to be captured earlier on in the supply chain by other schemes (including the CCA and a possible EPC). Higher embedded-energy products (including refrigerated foods) would cost more.

To conclude, refrigeration has yielded enormous benefits. It has made our food safer to eat and helps to reduce waste. However even in these areas, these gains have not been unalloyed. As with all technologies perhaps, it has created opportunities for new problems to emerge in just the areas which it assists.

The interactions among refrigeration, packaging, food transport, food product innovations and various socio-economic developments have helped create cultural norms and practices which are highly energy dependent. Technology and behaviour thus feed one another.

As such, refrigeration serves as a symbol, or marker of unsustainable energy use and behaviours in the food system. Policies need to address, therefore, not just refrigeration energy *use*, but also refrigeration *dependence*. While energy efficiency measures and novel technologies are important and indeed essential, they do not tackle the reasons *why* we need to use refrigeration: that is, what it is about the foods we eat and the way we manage our lives that renders refrigeration necessary; nor do efficiency measures address how refrigeration has catalysed additional developments in the food supply chain which have damaging consequences for greenhouse gas emissions.

We hope that this paper provides a starting point for exploring this issue further.

INTRODUCTION

The focus of this paper is on food refrigeration: what its environmental impacts are, how it has come to be so essential to the way we manage our food system, and what we might be able to do to reduce its associated greenhouse gas emissions.

The paper is structured as follows:

Section 1 examines what we know about the contribution that refrigeration along the food supply chain makes to the UK's greenhouse gas emissions and where the gaps in our knowledge lie.

Section 2 looks at what is known about ways of reducing emissions through improvements in energy-efficient practices and investments, through the development of new technologies and through changes in the commercial and institutional context. It highlights some of the policies that have been put in place or are being considered that seek to reduce refrigeration energy use.

In Section 3 published projections of future refrigeration energy use are analysed.

Section 4 asks how society has grown to become so dependent upon refrigeration and highlights the social, economic, cultural and commercial developments that may have fostered this trend. In Sections 5 and 6 the relationships between refrigeration and waste, and between refrigeration and food safety, are then discussed.

Section 7 sketches out what a lower refrigeration system might look like and whether policies that currently exist, or which could be developed, might help to achieve it.

Section 8 contains a summary of the conclusions of the report. Finally, we offer some recommendations for further action and research.

Background to this paper

This research forms part of the work of the Food Climate Research Network (FCRN), a three-year project funded by the Engineering and Physical Sciences Research Council and based at the University of Surrey.

The paper is based on a review of the relevant literature. It also builds upon the discussions made and presentations given at a seminar held by the Food Climate Research Network and hosted by the University of Manchester in September 2006. Acknowledgements can be found at the end of this report.

A note on terminology

In the text that follows, emissions for refrigeration are sometimes expressed as a percentage of the UK's greenhouse gas emissions and of the UK's total carbon dioxide (CO_2) emissions. The UK's total greenhouse gas emissions are, according to the latest Defra method of reporting, 179 million tonnes of carbon equivalent (656 million tonnes of CO_2 equivalent). Carbon dioxide emissions only stand at 153 million tonnes of carbon or 561 million tonnes CO_2. These figures are lower than previous estimates because they are net of carbon uptake by soils and vegetation.[1] To convert from carbon to carbon dioxide the figure should be multiplied by 44/12.

[1] *UK Emissions of Greenhouse Gases: Latest figures*, Defra, http://www.defra.gov.uk/environment/statistics/globatmos/

The word ‘refrigeration’ is mainly taken to mean both chilling and freezing – that is all forms of temperature control. Where refrigeration – maintaining food at a cool temperature – is discussed as distinct from freezing, the context should make this plain.

Acronyms and abbreviations

CCA	Climate Change Agreement
CFA	Chilled Food Association
CSDF	Cold Storage and Distribution Federation
Defra	Department for the Environment, Food and Rural Affairs
DfT	Department for Transport
DTQ	Domestic Tradeable Quota
ETS	Emissions Trading Scheme
EPC	Energy Performance Commitment
ESCO	Energy Service Company
EST	Energy Saving Trust
EU	European Union
EU-15	The 15 countries of the EU before expansion on 1 May, 2004
EuP	Energy-Using Products (directive)
FCRN	Food Climate Research Network
FrPerc	Food Refrigeration and Process Engineering Research Centre
FSA	Food Standards Agency
GHG	Greenhouse gas
GWh	Gigawatt hour
GWP	Global Warming Potential
HC	Hydrocarbon
HFC	Hydrofluorocarbon
MtC	Mega-tonnes of carbon
1-MCP	1-methylcyclopropene
MTP	Market Transformation Programme
TWh	Terawatt hours

SECTION 1: FOOD REFRIGERATION RELATED ENERGY USE: WHAT DO WE KNOW?

Food chain refrigeration energy use is an area of great uncertainty and as yet no comprehensive and authoritative estimates as to its overall consumption exist.

a. Initial estimates

Many factors complicate the task of quantifying cold chain related energy use. For a start there is a huge number of individual food enterprises in the UK: 102,511 retail outlets sell food, over 6,400 of which will be large supermarket stores. The remainder comprise premises of varying size and format – from garage forecourts to 'Express' style multiple-owned convenience stores, to tiny newsagents.[2] To these retail numbers should be added the 13,748 wholesale enterprises and the 262,948 catering outlets[3] which will also use refrigeration to a varying degree.

The equipment used by these enterprises varies widely both by type and by age, meaning that no easy assumptions can be made as to their energy consumption nor to the efficiency of that consumption. Importantly there will also be wide variations in the way the equipment is monitored and managed and this too will have a major bearing on energy use. Comprehensive accurate measurement taking all these factors into account is difficult, and perhaps impossible.

Some partial estimates have, however, been made. For example, the Market Transformation Programme calculates that the energy used for commercial refrigeration amounts to about 16,107 GWh (2005 figures), which, using standard electricity conversion factors, equates to 1.9 million tonnes of carbon, or 1.2% of the UK's of total CO_2 emissions. These figures are for energy related emissions only and do not include the global warming impacts resulting from the leakage of refrigerants. It is assumed here that these increase total GHG emissions by around 15%.[4] The non-CO_2 greenhouse gases account, in the national inventory, for around 15% of the UK's total greenhouse gas emissions. Hence we assume here that the contribution of refrigeration to total greenhouse gas emissions is the same as the CO_2 contribution of refrigeration to the UK CO_2 total – in other words, 1.2%.

This figure covers energy use in all commercial refrigeration applications, and not just food. For *food and drink* related refrigeration emissions alone (ie. including refrigeration in supermarkets, catering outlets, pubs and cellars, staff catering and so forth) emissions work out at 1.46 million tonnes of carbon, equivalent to 0.97% of the UK's CO_2 emissions.[5] As above, the points made about refrigerant leakage apply too, thus the contribution to the UK's total GHG emissions is also 0.97%.

Of this 0.97%, MTP data show that energy use by supermarket retail outlets equates to about 0.16% of the UK's CO_2 emissions, and hence greenhouse gas emissions (241,867 tonnes of carbon).[6]

None of these figures includes manufacturing stage energy use, mobile refrigeration, nor refrigeration in large commercial cold stores by which we mean national distribution centres and such like.

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[2] IGD, *UK Grocery Retailing factsheet*, May 2006, http://www.igd.com/CIR.asp?menuid=51&cirid=114
[3] *Food Industry Sustainability Strategy*, Defra, 2006, http://www.defra.gov.uk/farm/policy/sustain/fiss/
[4] *Sustainable Development: Achievements and Challenges in the Refrigeration Sector*. Bulletin of the International Institute of Refrigeration, no. 2002-5, http://www.iifiir.org/en/doc/1045.pdf
[5] Romano Pehar, personal communication, November 2005
[6] Romano Pehar, personal communication, November 2005

Some idea of the energy used in food manufacturing can be found from data reported as part of the Climate Change Agreements (CCAs) of the Food and Drink Federation, British Poultry Council and British Meat Federation. Estimates by compliance consultants Enviros (who help manage these agreements) suggest that refrigeration at the manufacturing stage requires about 2,396 GWh of electricity. This is about 280,000 tonnes of carbon, or 0.18% of the UK's greenhouse gas emissions.

There is also domestic refrigeration to consider. Turning again to data provided by the MTP[7], domestic refrigeration contributes 1.24% to the UK's CO_2 emissions.

Adding these all together it appears that from available data that the contribution of the refrigeration sector as a whole to the UK's GHG emissions is about 2.4%.

This is certainly an underestimate since refrigeration transport is not included in this estimate and nor are commercial cold stores.

Table 1: Emissions associated with food refrigeration life cycle stages

Refrigeration life cycle stage	Carbon emissions million tonnes	Contribution to UK greenhouse gas emissions total
Manufacturing stage	0.28	0.18
Food retail	1.46	0.97
Domestic	1.9	1.24
Mobile refrigeration	unknown	unknown
Total	**3.64**	**2.39**

Crucially too, refrigeration emissions generated during the course of storing, processing and transporting goods produced overseas for UK markets will also need to be included if we are to gain an accurate picture of the UK's refrigeration-related impact. As Table 2 shows, self sufficiency in a number of refrigeration-dependent products is low.

Table 2: UK imports of refrigeration-dependent foods

Product	% imported	Data source
Fruit	90	*Agriculture in the UK,* Defra, 2005
Vegetables	40	*Agriculture in the UK,* Defra, 2005
Cheese	40	*Dairy Facts and Figures 2003*, Milk Development Council, Cirencester, 2004
Butter	39	*Dairy Facts and Figures 2003*, Milk Development Council, Cirencester, 2004
Yoghurt	30-42	Derived from data by Mintel, National Food Survey and Milk Development Council
Beef	26	*Agriculture in the UK,* Defra, 2005
Pork	38	*Agriculture in the UK,* Defra, 2005
Ham and bacon	66	*Agriculture in the UK,* Defra, 2005
Sheep meat	13	*Agriculture in the UK,* Defra, 2005
Poultry	10	*Agriculture in the UK,* Defra, 2005

Hence the refrigeration-related emissions associated with our *consumption* of foods (thereby including imports and excluding the smaller quantity of food we export) may well be considerable.

[7] *Sustainable Products 2006: Policy Analysis and Projections*, Market Transformation Programme, July 2006

b. Research underway

Defra has recently funded a project, led by the University of Bristol's Food Refrigeration and Process Engineering Research Centre (FrPerc) which focuses on food refrigeration's impacts and the options for emissions reduction. As regards reductions, the emphasis of this project is not just on the technological barriers to innovation and uptake but on the policy, commercial and managerial obstacles too. These are very significant indeed, as is discussed in Section 2.

The project scope encompasses all stages from post-harvest or slaughter through to the retail outlet (omitting the domestic stage) and consists of three phases:

- A mapping study quantifying food refrigeration impacts at all stages through to the retail outlet
- A study to identify what refrigeration technologies are available, ranking them in order of their ability to save energy
- Studies to examine the feasibility of current unexploited technologies and to develop projects, where possible, which further knowledge as to how these might be further exploited.

The FrPerc project also seeks to identify which food types are the most refrigeration intensive. While research is still at an early stage, initial findings suggest that the meat sector appears to be the most energy intensive of all sectors.

It is important to note again that the Defra-funded study looks only at refrigeration energy used in the UK and hence, to the extent that refrigerated imports exceed refrigerated exports, they will underestimate the total refrigeration burden of the food and drink we consume.

SECTION 2: THE SCOPE FOR REDUCING REFRIGERATION ENERGY USE

This section looks at what is known about ways of reducing emissions through improvements in energy-efficient practices and investments, through the development of new technologies and through changes in the commercial and institutional context. It highlights some of the policies that have been put in place or are being considered that seek to reduce refrigeration energy use.

a. Improving energy efficiency

Considerable scope exists for reducing emissions from cold storage. Much of the equipment currently in use is very old and hence highly inefficient.[8]

It is generally considered that energy savings of between 20%[9] [10] and 50%[11] are possible through the proper specification, use and maintenance of equipment. The potential energy savings for mobile refrigeration equipment can be particularly substantial. One estimate by the International Institute for Refrigeration suggests that energy use for chilled food transport could be cut by 50%.[12] For frozen foods the savings will be lower, but still significant.

Some refrigeration energy savings will be achievable simply through the correct maintenance of existing equipment: ensuring that any worn-out door seals are repaired, that doors are shut and leakages identified, for example. Further savings are predicated on the correct specification of new or replacement equipment.

There is in fact plenty of information and advice available from bodies such as the Carbon Trust[13] and the Institute of Refrigeration. The latter is running a number of projects on energy efficiency,[14] including the development of a Code of Practice for refrigeration in supermarkets. The International Institute of Refrigeration also provides a great deal of advice on energy efficiency and cleaner technologies.[15] To summarise some of this advice,[16] the following measures can lead to substantial efficiency gains:

Minimise the load

- Reduce heat gains by keeping doors shut, ensuring the rapid transfer of temperature-controlled food from one unit to another
- Insulate well
- Reduce fan power: this can yield a double benefit[17]
- Do not over-design equipment, or it can operate at sub-optimal efficiency
- Use free cooling (for example, by taking advantage of lower night-time temperatures) and heat recovery

[8] John Hutchings, Cold Storage and Distribution Federation, personal communication, December 2005
[9] Robert Heap, Cambridge Refrigeration Technology, comment made at FCRN refrigeration seminar, Manchester, September 2006
[10] John Hutchings, Cold Storage and Distribution Federation, personal communication, December 2005
[11] See for example *How to improve energy efficiency in refrigerating equipment*, International Institute of Refrigeration, November 2003, http://www.iifiir.org/en/doc/1015.pdf
[12] *Refrigerated transport: progress achieved and challenges to be met*, International Institute of Refrigeration, August 2003
[13] See for example publications at http://www.carbontrust.co.uk/publications
[14] See http://www.ior.org.uk/ior_general.php?r=O0ENRSKHAL
[15] See for example literature available at http://www.iifiir.org
[16] *Energy Efficient Technology*, presentation given by Robert Heap, Cambridge Refrigeration technology, FCRN seminar, Manchester, September 2006
[17] The fan blows air around the cold store or mobile unit

Minimise the temperature difference[18]

- Do not over freeze or cool products – a 1 ºC less lift requires 2-4% less power[19]
- Design for efficiency at typical conditions – this can be warmer in some countries than others
- Avoid head pressure control[20]
- Minimise pressure drops in pipes

Look at the controls

- Use the best temperature controls available
- Use variable speed drives[21]
- Match capacity to load – do not under- or over-load
- Minimise lighting load (this is particularly relevant in supermarkets)[22]

Maintain properly

- Keep heat exchangers clean – dirty heat exchangers increase temperature lift
- Minimise leakage: if a refrigeration system loses 15% of its refrigerant then its energy requirement can double for a given amount of cooling[23]
- Check controls are operating correctly
- Check the application has not changed[24]
- Use specialists, not the odd job man

The cost implications of these measures are not clear. Some will cost nothing or very little (keeping doors shut, or matching capacity to load). Others will require investment in new equipment, or the retrofitting of existing plant. The proper training of staff will also be an expense. While such investment reduces costs in the long run, the initial outlay may be significant and this is often a barrier to the uptake of efficiency measures, as is discussed in Section 7 below.

Energy use by mobile refrigeration units is an area of potentially very great concern. The general view is that much mobile equipment is operated very inefficiently[25] although, in the absence of data, its total impacts relative to other stages in the cold chain are not known. The Department for Transport (DfT) is not currently funding any projects that specifically focus on improving the efficiency of mobile refrigeration units.[26] This is an area that would clearly benefit not only from further research, but also from inter-departmental and inter-sectoral collaboration to improve the vehicle fleet as it stands, based on the cleaner technology that already exists.

Polices to improve energy efficiency

A number of policies have been implemented or are being considered, which seek to improve the energy efficiency of both commercial and domestic refrigeration equipment. The main ones are summarised here:

[18] For example, the refrigeration unit should not be placed near a boiler
[19] In other words, for every 1 ºC drop in temperature, an additional 2-4% of power is needed
[20] According to Robert Heap from Cambridge Refrigeration Technology, in some systems, the control mechanism requires (or is said to require) a certain pressure level in the refrigeration circuit to work properly. Head pressure control keeps this pressure up by artificially maintaining a high pressure (and temperature) at the compressor outlet whenever the operating conditions do not supply this pressure. This is inefficient
[21] Compressors and fans can be run at a fixed speed or can have inverter drives allowing speed to be varied to match demand, which saves a lot of energy
[22] Store lighting generates heat which will need to be countered by the refrigeration system
[23] Robert Heap notes that in this case the system may still appear, if unmonitored, to be working perfectly well and may not actually break down until even more refrigerant is lost
[24] For example, if throughput increases, make sure the system in use is not working above its capacity
[25] Various comments at FCRN seminar, Manchester, September 2006 and personal communications
[26] Department for Transport, personal communication, September 2006

Energy Using Products (EuP) Directive

This EU Directive, still in its initial stages, is developing design requirements to address the environmental effects of energy-using products throughout their life cycle. Products must then meet set criteria in order to be placed on the market and the inefficient ones removed. In time, the EuP Directive will in effect act as a ban on inefficient equipment. Fourteen preparatory studies are currently underway. It is envisaged that for commercial refrigeration technologies, the study will be completed in July 2007 and adopted by the European Commission in 2008.

Climate Change Agreements

The refrigeration sector's Climate Change Agreement (CCA) has only recently been established (November 2006). It commits participants to reducing energy use by between 12% (from a 2005 baseline) by 2011 with an intermediary target of 5% reduction by 2008.[27] A further 7% is to be achieved by the final milestone in 2011. Those achieving the full 12% reduction are awarded a discount on the Climate Change Levy until March 2013.

The Cold Storage and Distribution Federation (CSDF) estimate, that around 300 or more sites could eventually participate in the CCA.

The Enhanced Capital Allowance Scheme

The Enhanced Capital Allowance Scheme enables businesses to claim 100% first year capital allowances on investments in energy-saving technologies and products. Businesses are now able to write off the whole cost of their investment against their taxable profits of the period during which they make the investment.

The MTP estimates that for refrigeration, so far the Scheme has resulted in energy savings of 1.4 TWh in the year 2004-5,[28] equivalent to 163,800 tonnes of carbon.

At present the scheme only applies to a selection of technologies. There is a possibility that new thresholds will be set and the range of products eligible extended to include, for instance vending machines and cold rooms.

Domestic energy labelling schemes

The EU labels a range of domestic appliances according to their efficiency. In addition the UK's Energy Saving Trust (EST) runs an 'Energy Saving Recommended' scheme, with the recommended products eligible to bear a logo. There are several ways in which these schemes could be modified to raise energy efficiency standards. For a start, removing the lowest-rated appliances from the ratings system altogether, and tightening the criteria would make a significant difference.

In addition, the issue of relative versus absolute energy use needs to be addressed. At present, cold appliances are awarded energy-efficiency ratings on the basis of their energy use per cubic foot. It is technically easier for a large refrigerator to receive an A rating than a small refrigerator. While this can mean that over the course of a year a large A-rated fridge can use more energy in absolute terms than a small but B-rated appliance, there will also be situations where a large efficient fridge can, in absolute as well as relative terms, be more efficient than a smaller one.

[27] Cold Storage and Distribution Federation http://www.csdf.org.uk, accessed 26 November 2006
[28] *Energy performance standards for the commercial refrigeration industry*, Case Study 4, Market Transformation Programme, 2005

The challenge, from an environmental perspective, is for manufacturers to produce a fridge which generates the least possible emissions in absolute terms taking into account both size and energy use per cubic foot. In other words if a large fridge and a small fridge use the same amount of energy per cubic foot, whereas under today's system they receive the same rating, in absolute terms the smaller fridge will use less energy. As such it should be awarded a higher rating.

Eurovent Energy Efficiency Classification

Eurovent is a European voluntary classification system for commercial chillers (including air conditioning) that classifies products according to their efficiency, with A being the most efficient and G the least.

Future steps that could be considered using this scheme might be removal of the least efficient products, raising standards, and an expansion of the scheme to include a wider range of products.

Energy Performance Commitment

In November 2006, Government published a consultation document outlining its proposals for an Energy Performance Commitment (EPC).

This is a scheme designed to cut carbon emissions from large commercial and public-sector organisations by 1.2 million tonnes per year by 2020. The intended targets of EPC are non energy-intensive large organisations – whose mandatory half-hourly metered electricity use is above 3,000 MWh per year – who are not included in the EU Emissions Trading Scheme (ETS) and CCAs. There are about 5,000 of these organisations,[29] including supermarkets, hospitals, hotel chains, local authorities and central Government. Defra calculates that together they account for around 15 MtC of carbon emissions or nearly 10% of the UK's entire economy-wide carbon (not GHG) emissions.

Smaller businesses – those who consume less energy – will be excluded from the scheme since the administrative costs could outweigh the value of energy savings.

b. Novel and alternative technologies

The deployment of cleaner technologies and good energy management have, as discussed, the potential to yield substantial savings. It is important to consider whether the more novel technologies either already on the market or nearing the commercial stage might be able to deliver more radical savings than efficiency measures alone. The following paragraphs consider a few of the technologies that are currently available or being developed.

[29] *Consultation on measures to reduce carbon emissions in the large non energy-intensive business and public sectors*, Defra, November 2006
http://www.defra.gov.uk/corporate/consult/carbon-emissions/consultation.pdf

Polygeneration and trigeneration

Trigeneration is one technology with cold-chain applications that is currently receiving considerable attention. Defra is funding a trigeneration project at Brunel University and it is thought that the technology could reach the commercial stage by 2008-09.

In essence, trigeneration takes cogeneration a stage further: a combined heat and power plant is modified to provide heat, electricity and cooling. Figure 1 provides a schematic illustration of a trigeneration plant.

Trigeneration has the potential to double the average efficiency of a refrigeration system. Typical system efficiencies using conventional store boilers are about 38% (in other words, 62% of the energy used is wasted) whereas with trigeneration efficiency rises to about 76%.[30] The carbon reduction potential of the trigeneration model can be improved further by the use of biomass as a fuel source.

On a wider European level, the European Commission is funding the Optipolygen,[31] a project that examines the potential for polygeneration across the EU-15 (the 15 countries of the EU before the expansion in May 2004). Polygeneration is defined as the use of multiple energy inputs to create multiple energy outputs and encompasses both systems that require heat (such as cooking) and coolness (refrigeration). Combined Heat and Power (CHP) is one example of a polygeneration system, but the most integrated example would be a trigeneration plant fuelled by biomass or biogas and producing heat, electricity and refrigeration.

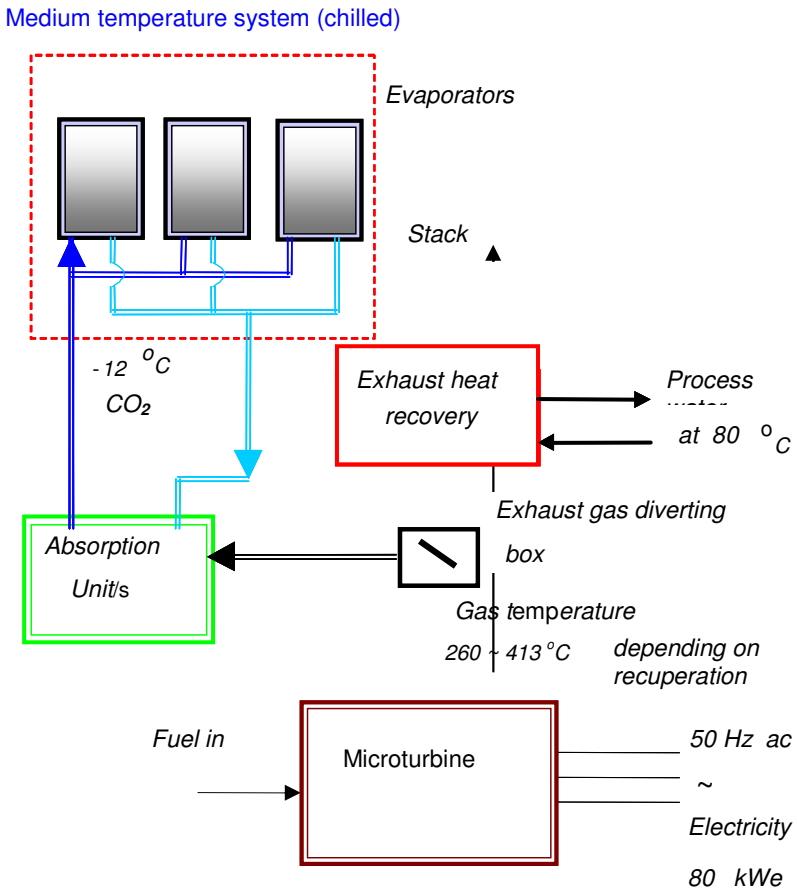
Clearly trigeneration will not be suitable for all plants. However, initial calculations made by the Optipolygen project suggest that trigeneration (that is, refrigeration-related applications) has the potential to save 6.6 million tonnes of carbon dioxide across the EU-15; the figure for polygeneration is higher still at nearly 21 million tonnes of CO_2. For the UK, the potential CO_2 savings from trigeneration are estimated to be about 0.7 million tonnes. It should be stressed that these figures are very provisional – more accurate estimates will emerge as the project progresses.

This sounds like a great deal of saved CO_2. However, to put these figures into context, the UK emits around 656 million tonnes of CO_2 equivalent per annum. Hence trigeneration could shave about 0.1% off the UK's total greenhouse gas emissions. Obviously the savings in relation to total refrigeration-related GHG emissions will be more significant.

On the EU scale, total CO_2-equivalent emissions from the EU-15 in 2004 came to 4,277.4 million tonnes. Potentially polygeneration as a whole could therefore knock 0.5% off the total; from trigeneration alone the reduction will be lower at 0.15%.

[30] Doug Marriott, Doug Marriott Associates, comment made at FCRN seminar, Manchester September 2006 and personal communication
[31] See http://www.optipolygen.org

Figure 1: Schematic illustration of a trigeneration plant



Source: Doug Marriott Associates Ltd.

The question of value for money – that is, how best could money aimed at reducing GHGs be spent, is an important one. It would be particularly interesting to see how the savings from polygeneration compare with what could be achieved by basic improvements and investment in energy efficiency. For example, based on the (very approximate) estimate given in Table 1 above, which puts UK refrigeration emissions at 3.64 million tonnes of carbon equivalent (13.3 million tonnes of CO_2) then the application of trigeneration technology would reduce emissions here by roughly 5%. This is somewhat low compared with the 20% reduction that energy efficiency measures (see above) are estimated to be able to achieve.

It needs to be stressed however that the 20% efficiency saving posited above will not be cost-free. Some equipment may be so old or inherently inefficient as to be irredeemable and new equipment will need to be purchased. Where applicable, a trigeneration plant will clearly save far more energy than a conventional plant. Moreover, research to improve energy efficiency in food refrigeration will have benefits for *all* industry sectors where refrigeration and air conditioning are used.

Commercial cooling equipment (air conditioning as well as refrigeration) accounts for about 8% of the UK's total electricity use[32] and about 2%[33] of the UK's CO_2 (and

[32] *Sustainable Products 2006: Policy Analysis and Projections*, Market Transformation Programme, July 2006 and DUKES energy statistics, Table 5.2 Electricity supply and consumption http://www.dtistats.net/energystats/dukes5_2.xls

GHG) emissions. Air conditioning is growing in importance; it now accounts for 37% of all commercial cooling energy use and its share is set to grow over time.[34]

Further research into the financial implications of investing in cleaner technologies would be useful to identify where the greatest potential for savings can be achieved.

HFC-free technology

Another technological development which is already on the market is the substitution of hydrofluorocarbons (HFCs) with hydrocarbons as a refrigerant.

HFCs, while efficient refrigerants, have a global warming potential (GWP) thousands of times greater than that of carbon dioxide. At present there is no legal requirement to phase out their use; the EU's F-Gas regulation introduces a number of measures to manage equipment containing F-gases,[35] such as leak testing, but there are no indications of a ban either now or in the future. Austria and Denmark have however put in place stricter controls than other EU members.

It is worth noting too that the EU F-gas Directive which deals with fluorinated gases used for mobile air conditioning in vehicles (MACs) will phase out HFC 134a for this use from 2011. The Regulation will be reviewed after four years, effectiveness assessed and F-gases restrictions on other applications will be identified. One observer notes that '*Inevitably, the F gas regulation will be enhanced after 2011 and with the F gas ban in MACs setting a precedent, further bans are possible.*'[36]

Note that the F-gas regulations also impose a legal obligation on equipment operators to use only certified-as-competent technicians. It has been suggested that this obligation, if properly followed and enforced will save lead to energy and refrigerant savings through the proper maintenance of equipment.[37] There will also be a ban on refrigerant fluid sales to uncertified people.

It has been argued[38] that the continued use of HFCs reduces our chances of preventing 'dangerous' climate change to a possibly critical degree (see box below). According to data published by the US National Academy of Science,[39] the global warming resulting from the projected increase in the use of HFCs alone could, if unchecked, amount to 0.15-0.2°C in 2050. This erodes the very small safety margin of 'acceptable' temperature increase (0.4-0.8°C) that we have left.

[33] *Sustainable Products 2006: Policy Analysis and Projections*, Market Transformation Programme, July 2006
[34] *Sustainable Products 2006: Policy Analysis and Projections*, Market Transformation Programme, July 2006
[35] Fluorinated greenhouse gases – fluorocarbons and sulphur hexafluoride
[36] Nicholas Cox, Earthcare Products Ltd, personal communication, November 2006
[37] Robert Heap, Cambridge Refrigeration Technology, personal communication, November 2006
[38] *HFC Elimination – Significance and Prospects*, presentation given by Doug Parr, Greenpeace, FCRN refrigeration seminar, Manchester, September 2006
[39] Hansen, J. and Mki. Sato (2004). Greenhouse Gas Growth Rates. Proc. Natl. Acad. Sci. 101, 16109-16114, doi:10.1073/pnas.0406982101

Climate change and the warming commitment

An emerging scientific consensus suggests that an increase in average global temperatures of 2°C above pre-industrial levels tips us into the likelihood of 'dangerous climate change' – a situation when the earth's climatic mechanisms spiral out of control leading to potentially catastrophic consequences.[40] The existing concentration of gases in the atmosphere, combined with time-lags in the earth's climate mechanisms, mean that we are already 'committed' to a temperature rise: if no more fossil fuels were burned and no more greenhouse gases emitted into the atmosphere as from this moment, the world would still continue to warm. Research undertaken by NASA suggests that this warming commitment adds about 0.6°C or so to the 0.6°C of warming that has already occurred – in other words temperatures will rise to 1.2°C or more above pre-industrial levels. Another study published in *Science* estimates that we may be committed to a warming of over 1°C above the 2000 average which itself has increased by 0.6°C above pre-industrial levels,[41] a 1.6°C commitment in all.

Hydrocarbons (HCs) are an alternative to HFCs which have minimal direct global warming effect. However, it is very important to ensure that systems designed to use alternative refrigerants do not use more energy than conventional systems. Providing this is achieved – and there is considerable commercial inertia to be overcome – there will always be a reduced environmental impact due to the elimination of fluids with high GWP.

Hydrocarbons and other non-HFC coolants are in fact already used to a degree by three major multinational industries – Coca-Cola, McDonald's and Unilever – and all have reported energy savings as a result of the switch-over.[42]

One industry provider of hydrocarbon refrigerants reports findings of trials, shown in Table 3 below, where in most cases energy efficiency improved, sometimes by up to 15%,[43] relative to existing standard plant performance. To this is added another 5% through the avoided greenhouse gas contribution from the refrigerant gases.

Table 3: Refrigeration efficiency of cool appliances using hydrocarbon refrigerant

Application	Proportion of cases where Hydrocarbons (HCs) give best performance (COP)[44]				
	<10% improvement	10-20% improvement	>20% improvement	Total	Mean improvement
Domestic	63.9	13.9	5.6	83.3	6
Commercial	51.6	12.9	22.8	90.3	15
Air-conditioning	63	25.9	3.7	92.6	8.8
Heat Pumps	58.6	37.9	3.4	100	9.5

Source: *Assessment of Performance of Hydrocarbon Refrigerants*, D. Colbourne, Calor Gas Ltd., K. O. Suen, University College London

[40] *Avoiding Dangerous Climate Change*, ed. Hans Joachim Schellnhuber, Cambridge University Press, 2006
[41] Wigley, T.M.L. (2005). "The climate change commitment", *Science*, 307: 1766–1769
[42] *HFC Elimination – Significance and Prospects*, presentation given by Doug Parr, Greenpeace, FCRN refrigeration seminar, Manchester, September 2006
[43] *Energy-efficient refrigeration using hydrocarbon refrigerants*, presentation given by Nicholas Cox, Earthcare Products Ltd, FCRN seminar, Manchester, September 2006
[44] The COP (Coefficient of Performance) is a measure of refrigeration efficiency. The ratio of the rate of heat removed (cooling effect) to the rate of heat input required, expressed in the same units

While there may be conflicting opinions as to the energy efficiency of hydrocarbons within current design constraints there is, however, clear acknowledgement within the industry as a whole that high GWP HFCs will need to be phased out.[45] This will require the design of optimised equipment that enables alternative refrigerants to be used without compromising on efficiency. The rate at which this takes place, the extent to which alternatives need to be more fully developed before the change over is made, and the form that legislation should take, are the main issues of contention.

Packaging and related innovations: avoiding the need for refrigeration

One way of reducing refrigeration emissions is to develop packaging formats that obviate the need for it.

One well-known example is of course the steel can. While there will be considerable energy used in the extraction of the raw steel and the manufacture of the can, A US-based life cycle analysis[46] finds that overall, canned food is less carbon intensive than its frozen equivalents; for fresh foods the carbon footprint is fairly similar.

While there may be a perception that canned foods are not as 'healthy' as their fresh equivalents, other studies have shown that the nutritional value of canned foods (other than vitamin C which in this country is not a limiting vitamin) is good, and comparable with fresh – indeed for some vitamins, better.[47]

However, it is very clear that our taste for many canned foods – baked beans are a notable exception – is waning. [48]

Another possibility is food irradiation. This, while widely adopted in the US and in other parts of the world, has faced opposition in Europe both from the public and from consumer groups. While it may be that food irradiation could reduce reliance on the cold chain, several points need to be noted. The first is that the irradiation process may itself be energy intensive (no research on this matter was found) and so further investigation is needed here. Secondly, for bulk consignments it is very difficult to give a uniform irradiation dose to a bulk consignment without some parts being under-protected and others being damaged, making irradiation an impractical alternative to refrigeration.[49] Third, in practice irradiation tends to be used as a belt and braces safety measure rather than as a substitute for refrigeration.

Another option is SmartFresh. This is an established storage technique which aims to preserve the texture and commercial quality of fruit. Gases (1-MCP)[50] are introduced into the storage environment; these stop the ethylene, the gas that is naturally produced by fruit and which triggers ripening and decay, from affecting the fruit. By slowing the ripening process SmartFresh can extend both the storage and the in-store shelf life of the product. In theory the technology could help reduce cold storage requirements. In practice, this does not happen – fruit is stored at the same temperature as it would have been, but the apple is crisper than under normal storage

[45] Comments made at FCRN refrigeration seminar, Manchester, September 2006
[46] Ritchie, K. (2005). *From Farm to Table: An energy consumption assessment of refrigerated, frozen and canned food delivery*. A report prepared by Scientific Certification Systems Inc. on behalf of the Steel Recycling Institute, Pennsylvania, United States
[47] Ligthart, T., Ansems A. M., Jetten, J. *Eco-efficiency and nutritional aspects of different product packaging systems: an integrated approach towards sustainability*, Association of European Producers of Steel for Packaging, August 2005
[48] *Canned Meals and Meats* – UK. Mintel, April 2006 and *Frozen and Canned Fruit and Vegetables* – UK, Mintel, June 2005
[49] Robert Heap, Cambridge Refrigeration Technology, personal communication, March 2006
[50] 1-methylcyclopropene

conditions. Energy used to produce and apply SmartFresh gas is not known and would need to be taken into account when considering what energy-saving potential it might have. Moreover, SmartFresh is only suited to certain types of food.

Aseptic food packages such as cartons are another option, but they are not suitable for fresh unprocessed produce. It is also unclear whether, once the embedded energy of the carton itself is taken into account, their use would in fact save energy.

A report commissioned by the Faraday Food Processing Partnership[51] examines novel technologies such as these for extending the shelf life of foods. The emphasis of the report is not, however, on reducing energy use but rather on reducing manufacturers' costs, increasing profitability, extending shelf life (which is not at all the same as reducing energy use) and reducing risk. The technologies reviewed focus on highly processed foods such as ready meals and are predicated on the existence (and continuance) of long supply chains, refrigeration at earlier stages in the supply chain, and existing patterns of distribution. The thrust of the report is not so much to reduce energy impacts but, in the context of an increasingly risk-averse culture, to reduce, in the most cost-effective manner, any possibility of food safety problems arising.

c. The commercial and institutional context

It is often emphasised that the barriers to reduced energy use (in all sectors, and not just refrigeration) are less technological than institutional. Often the energy-saving technology exists, but the decision-making processes get in the way. This section takes a closer look at this issue, and the possible ways forward

People management and decision-making

It has been suggested[52] there are three main types of stakeholders in the refrigeration chain: those responsible for developing the technology, those responsible for managing it, and those who simply use it. Obviously there will be significant overlap between categories but the distinctions (illustrated in Figure 2) will do for the purposes of the discussion that follows.

There are perhaps a few hundred people who fall into the first category – those directly involved in the work of improving and developing cleaner technologies. There are more people, measurable in thousands, in the second category – those responsible in manufacturing and retailing for managing and maintaining equipment. And there are millions of us – the buyers of food – who fall into the third category.

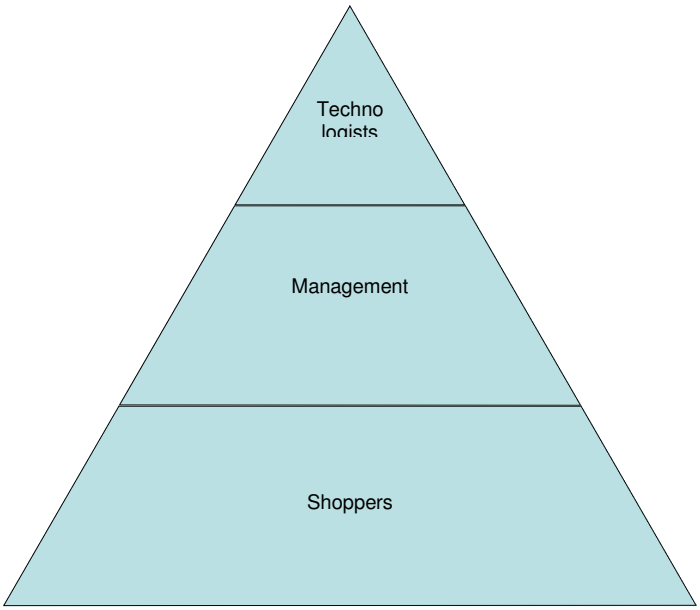
Each type of stakeholder will influence energy use, and the efficiency of its use, in the supply chain.

While those responsible for developing technologies have a pivotal role in making more efficient equipment available and marketable, the technology will achieve savings only if it is specified and if it is maintained correctly. If decision makers fail to specify or purchase this cleaner equipment (or specify / purchase the wrong cleaner equipment) and if they fail to ensure that their staff are managing it correctly, then that equipment will not operate efficiently.

[51] *Extension of Product Shelf-life for the Food Processor*: A strategic report compiled for the Food Processing Faraday by the Scientific and Technical Information Section, Leatherhead Food International. Undated

[52] Doug Parr, Greenpeace, comment made at FCRN refrigeration seminar, Manchester, September 2006

Figure 2: Categories of stakeholders making decisions about refrigeration



The base of the pyramid, we the consumers, with all our different ways of shopping and handling our food, represents a major challenge. As highlighted above, practices and dependences surrounding food refrigeration will clearly need to be addressed as part of any cohesive sustainable consumption policy. While this needs to start happening now, change will hardly happen overnight.

In the first instance, then, tackling the 'middle stakeholders' may, in the short term, be the most effective way of improving energy efficiency in the supply chain.

Short-term savings versus whole-life costing

One of the main barriers to companies investing in energy-efficient equipment and services is that short-term cost savings, or opportunities to increase revenue, are very often given priority over long-term life cycle savings.[53]

It can be the case that even when the long-term advantages are quantified and set out, the desire to cut costs in the short term, or to buy a familiar product ('let's go for the same as last time') is overwhelming. Traditional or long-standing industry purchasing relationships also have a part to play – a product is bought from the same supplier time and again because it offers familiarity and predictability.

These relationships can run through the whole of the supply chain. For example, compressor manufacturers have, on a long-standing basis, received technical support from HFC refrigerants makers (e.g. DuPont or Solvay) rather than from HFC-free refrigerant makers. Hence, manufacturers of compressors and refrigerants alike become 'locked in' to environmentally damaging products and practices.[54] The processes, and associated resource requirements, of standardisation and equipment certification (e.g. for safety) also reinforce this 'lock-in' effect.

[53] Point emphasised repeatedly at FCRN refrigeration seminar, Manchester, September 2006
[54] Point made at FCRN refrigeration seminar, Manchester, September 2006

In order to break this mutually reinforcing cycle, one way forward might be to bring a group of compressor manufacturers together with refrigerant manufacturers to collaborate in developing new systems and services.[55] This, potentially, would enable them to develop commercial relationships using new technology which itself might have first-mover commercial advantage. The same process could be applied in the case of other technologies and associated relationships.

Making use of ESCOs

The proper maintenance and management of refrigeration equipment can be a considerable challenge particularly when one considers that some supermarket refrigeration systems entail around half a mile of pipe work.[56] One option is to contract out the task of managing, and where necessary upgrading this equipment, to an Energy Service Company (ESCO).

A retailer using an ESCO would not so much buy refrigeration equipment, as a cooling service. The supermarket could specify certain parameters as regards store layout and the customers' ability to reach products; it would then leave the ESCO to specify, provide, maintain, monitor and improve on equipment. Since the ESCO, under the contractual terms, would pick up the energy bills it would be in their interests to ensure that both equipment and management of that equipment were as efficient as possible.

The potential for conflict of interests between those of the ESCO (to maximise efficiency) and of the retailer (to ensure that the products are displayed in a visually attractive, easily accessible format) certainly exists, but is not insurmountable. The solution will lie in ensuring that the right specifications are set out and agreed upon at the outset; if the supermarket wants open display cabinets, however intrinsically inefficient these may be, then this can be possible. Since the energy costs of operating that equipment will be higher, the contract between the two parties should reflect this. In short, the supermarket negotiates a monthly rent for cooling services, which could include specifications such as the temperature to be maintained and even staff training.[57] Included in the contract could be a 'shared savings' agreement whereby the financial gains from energy savings can by shared between the retailer and the ESCO,[58] and will be incorporated into the details of the contract.

Choice editing

The middle section of the pyramid includes not just those who specify and manage commercial equipment but also the retailers of domestic equipment to householders. A recent report from the Sustainable Development Commission, *I Will if You Will*,[59] coined the useful phrase 'choice editing', which already appears to have gained currency with retailers. This in effect means that retailers of domestic appliances can simply choose not to stock inefficient appliances. Since all stores in any case need to make decisions as to what to stock and what not to, environmental considerations simply need to be incorporated into these decision-making processes.

[55] Chris Foster, University of Manchester, personal communication, September 2006
[56] Comment made at FCRN refrigeration seminar, Manchester, September 2006
[57] Rebecca White, Environmental Change Institute, University of Oxford, personal communication, September 2006
[58] Rebecca White, Environmental Change Institute, University of Oxford, personal communication, September 2006
[59] *I Will if You Will: Towards sustainable consumption*, Sustainable Development Commission, London, 2006, see http://www.sd-commission.org.uk/publications.php?id=367

SECTION 3: TRENDS IN ENERGY USE: PUBLISHED PROJECTIONS

How is energy use in the food cold chain likely to change over time? Much depends on the direction that policy takes. The MTP models possible changes in energy use based on three possible scenarios, which it terms (a) *Business as Usual;* (b) *Policy* and (c) *Earliest Best Practice*.

The Business as Usual scenario envisages what is likely to happen if the market develops along its current course, without policy or other interventions.

The Policy scenario estimates what could be achieved through an ambitious, but feasible, set of policy measures if all stakeholders were to agree.

The Earliest Best Practice scenario is a projection of what would happen if everyone started buying the best available products, manufacturers put the best technologies on the market in a fairly rapid timescale, and Government took all reasonable (but ambitious) policy steps to mitigate adverse environmental impacts. The report suggests that while the Earliest Best Practice scenario may be ideal from an environmental point of view, it is unlikely to be realisable.

The MTP's baseline estimates of current energy use are based on stock modelling – that is, the use of historical information on demographic, technological, ownership and usage data. The MTP divides cold chain energy use into two categories, commercial and domestic.

For commercial refrigeration, the MTP projections indicate that energy use could rise by up to 6% or fall by 8%, depending on the policy context. For domestic refrigeration, it appears that energy use is set to fall, whatever the scenario, although the difference in savings between the best and worst case scenarios is twofold.

Table 4: MTP projections for refrigeration energy use, in three different scenarios

Commercial refrigeration	**2005 – GWh**	**2020 – GWh**	**% change**
Business as Usual scenario	16,107	16,793	+6
Policy scenario	16,107	14,962	-7
Earliest Best Practice scenario	16,107	13,228	-8
Domestic refrigeration	**2005 – GWh**	**2020 – GWh**	**% change**
Business as Usual scenario	16,220	12,875	-21
Policy scenario	16,220	12,047	-26
Earliest Best Practice scenario	16,220	9,872	-39

Source: *Sustainable Products 2006: Policy Analysis and Projections*, Market Transformation Programme, July 2006

Obviously the assumptions underlying these projections are critical. For commercial refrigeration, the modelling is based on existing market trends in new purchases. Estimates are made as to the average lifespan of the equipment, their average energy efficiency and their average annual use. The projected changes in energy use are based on assumptions concerning what (and when) new policies are introduced to promote the uptake of the most efficient equipment and best practice in its use. Note that these projections do not take into account changes in the uptake or use of refrigeration equipment in countries overseas that produce and transport foods for the British market.

As regards domestic refrigeration, MTP projections are based on Government-derived demographic forecasts[60] and current market data on average fridge/freezer ownership levels. It is assumed that every household has, and will continue to have, some form of fridge-freezer combination and that with the rise in single-person households, the overall number of fridges and freezers per head of population is set to rise.

Regarding trends in fridge sizes, the MTP assumes that these are unlikely to get much larger. [61] The Energy Saving Trust (EST), however, suggests that large American-style fridge-freezers may become more popular in coming years.[62] This is an area of potential concern since an A-rated typical American style fridge-freezer will consume around 150 KWh more per annum than the typical average UK-sized A-rated appliance. This says a great deal about the rating system itself, and is discussed further in Section 7 below.

The MTP projections assume that newer cleaner appliances, such as those deploying Vacuum Insulated Panel technologies are assumed to enter the market in coming years, although the speed with which they do so varies by scenario.[63] Assumptions are also made regarding the average lifespans of fridges and freezers, and take into account the possibility that some may serve as second fridges in the garage while others will enter the second-hand market.[64]

Both the MTP and the EST note the popularity of small cooler appliances – for example, wine coolers and beer chillers – for use in the bedroom, living room, car and on picnics. These tend to be glass fronted and very energy inefficient. In addition, they are, the EST notes, plugged in and forgotten, even when there are no drinks in them, so the unit can be cooling air, and little else, for most of its lifetime. The EST claims that these appliances can use 50% more electricity, per volume, than the equivalent under-the-counter larder type A-rated fridge.[65] Other energy-using refrigeration appliances appliances include ice-cream makers, and ice makers. The MTP may include these items in future studies, depending on data availability.

These projections are helpful and interesting but it is important to note that they assume no radical shifts in the sorts of foods we might choose to buy in the future. This is understandable since trends here are so very difficult to predict. However, the issue of refrigeration dependence, how it has arisen and where future trends might lead is in our view important. Section 4 offers a few preliminary thoughts on this topic.

One refrigeration-using area not covered by the MTP projections is the commercial cold storage sector. The term ‘commercial cold storage’ is taken here to mean temperature-controlled regional or national distribution centres where food is stored after leaving the manufacturer (in some cases the storage site may be owned by the manufacturer) before being trucked on to the retailer or other customer.

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[60] BNXS25: *UK Household and Population Figures 1970 – 2020*, Market Transformation Programme, 2005, http://www.mtprog.com/ApprovedBriefingNotes/BriefingNoteTemplate.aspx?intBriefingNoteID=325
[61] Jane Lee, modeller for MTP domestic appliances programme, personal communication, October 2006
[62] *The rise of the machines: A review of energy using products in the home from the 1970s to today*, Energy Saving Trust, June 2006
[63] BNC08: *Assumptions underlying the energy projections for domestic cold appliances,* Version 2.1, Market Transformation Programme, 18/09/06 http://www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNC08_2006October31.pdf
[64] BNC08: *Assumptions underlying the energy projections for domestic cold appliances,* Version 2.1, Market Transformation Programme, 18/09/06 http://www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNC08_2006October31.pdf
[65] *The rise of the machines: A review of energy-using products in the home from the 1970s to today*, Energy Saving Trust, June 2006

At present, figures quantifying energy use in this sector are not available. However, since the sector has recently negotiated a CCA with Defra, this information may soon be forthcoming. As part of the terms of the CCA, the sector will have to meet targets for absolute reductions in energy use/CO_2 or face financial penalties.

How are trends in refrigeration likely to affect the commercial sector? John Hutchings from the Cold Storage and Distribution Federation points out that the growth in chilled foods (see Section 4 below) will not necessarily mean that new cold stores will need to be built (which could make it harder to achieve absolute energy reductions). Since the through-flow of chilled foods is considerably more rapid than that of frozen food it does not lock up space in the cold store to the same degree. Higher volumes can be stored in the same space if they stay in store for less time. He also points out that since many cold stores are very old and will be replaced in the next few years, the probable result will be that absolute reductions in energy use and GHG emissions will be achieved even as demand for chilled food grows. This may well be the case at the commercial cold storage stage, but the pressure on refrigeration infrastructure at the retail, transport and domestic stages could well grow since the number of deliveries and the area devoted to retail display will both need to increase.

To summarise then, MTP projections suggest that under a 'business as usual' scenario, energy use is likely to increase at the commercial retail stage. This is likely to be compensated by a decline in energy use at the domestic and (according to John Hutchings) commercial cold storage stages. However, the MTP assumptions do not take into account possible changes in marketing, lifestyle and environment which could substantially alter their conclusions. In addition, they do not take into account energy use in mobile refrigeration units or in processing plants overseas which are likely to increase.

SECTION 4: REFRIGERATION DEPENDENCE IN THE FOOD SUPPLY CHAIN: HOW DID IT HAPPEN?

This section looks at the way that temperature-controlled storage has come to be the dominant means of preserving food in the developed world. It touches upon some of the social and economic trends that could be associated with refrigeration use and explores how trends in refrigeration dependence might develop over time.

a. A very brief history of refrigeration

We have been extending the natural life of our food one way or another for a very long time.[66] Salting, preserving in sugar or vinegar, smoking, drying and fermentation are all age-old methods which are still used today and which enable food to be stored or transported safely before consumption. Relatively more recently, we have taken enthusiastically to canning. This, developed in the early 1800s (the first factory in the UK was set up in 1813),[67,68] allowed the UK to import cheap beef and mutton from Australia. It has been argued that the can played an integral role in the expansion and maintenance of Britain's empires in the Victorian era.[69]

As for the preservation of foods by cooling, this is hardly a new technique. Indeed, most ancient cultures, including the Greeks, Roman, middle-Eastern peoples and the Chinese all harvested and stored ice for use in the summer months. There is evidence that the Chinese were cutting and storing ice by about 600 BC.[70] From the 8th century BC they were building ice houses and by the time of the Tang dynasty (13th century) huge blocks of ice were being lugged from mountains and frozen rivers and buried in caves or underground pits to act as giant refrigerators. [71] Historian Tannahill notes that by this time chilled food and drinks were *'an almost commonplace luxury'* in China.

Moving forward in time, the American Shakers were building ice houses with walls, roofs and floors insulated with sawdust and straw during the 17th century. One classic early 20th-century American children's novel in the *Little House on the Prairie* series gives a particularly engaging description of the process of ice cutting and storing.[72] In the UK, things were a little slower to get started but ice houses were a fairly common feature in stately homes by the 18th century.[73]

From about the mid 19th century onwards in the United States the ice-harvesting industry became big business. Breweries were perhaps the foremost user of the new technology since refrigeration enabled them to make a uniform product all year round. The meat-packing companies were, understandably, also major users.

The use of ice for domestic purposes also gained popularity. For the American middle classes, its ready availability enabled them to keep their foods cool with the aid of an ice box. This was a wooden box whose hollow walls were lined with tin or zinc and packed with various insulating materials such as cork, sawdust, straw or seaweed. A large block of ice was held in a tray or compartment near the top of the box. Cold air

[66] Some of the sources for this section include Wikipedia http://www.wikipedia.org , the *History Magazine* http://www.history-magazine.com, and the Canal Museum http://www.canalmuseum.org.uk
[67] See http://www.martinmathew.co.uk/canning.htm
[68] See http://www.open2.net/historyandthearts/history/food_timeline_html2.html
[69] Naylor, S. (2000). Spacing the can: empire, modernity and the globalisation of food. *Environment and Planning A*. volume 32 pp1625-1639
[70] Tannahill, R. *Food in History*, Penguin 1988
[71] Tannahill, R. *Food in History*, Penguin 1988
[72] Ingalls Wilder, L, *Farmer Boy*, first published in 1933
[73] Tannahill, R. *Food in History*, Penguin 1988

circulated down and around storage compartments in the lower section. The ice was delivered to customers via a fleet of horse-drawn ice delivery carts.[74]

Demand for ice was also growing in the UK and, with our milder climate, was such that it soon outstripped our ability to harvest it domestically. Hence ice began to be imported, initially from the US, and then from Norway, which quickly became our major supplier.[75] Major customers included the food industry (particularly the brewing and fish industries) and the associated transport sector. Ice was used to preserve goods travelling by rail, road and sea. While some domestic households followed the US example with the use of ice boxes, their use was by no means as common here as it was there.

The late 18th and early 19th centuries also saw considerable experimentation – both in the US and in Europe – with various mechanical cooling techniques. The first ice-making machines were patented in the 1830s, using coolants such as ethyl ether and liquid ammonia, and this enabled the technology (and its ensuing benefits) to become much more widespread. By the late 1870s, mechanical refrigeration was being deployed successfully to ship cheap frozen meat from Australia and New Zealand to the UK.

This had a major impact on the UK's consumption of meat. The historian Oddy[76] notes that from the 1890s onwards, London relied mostly on foreign meat supplied by chains of frozen-meat retailers. Slaughterhouses in the London area declined as the source of fresh meat: in 1889, the London County Council licensed 692 private abattoirs but by the end of the First World War, their numbers had dropped to 150. At the national level, by 1895 a third of the meat consumed in Britain was imported.[77]

Responding to this influx of frozen meat, cold-storage capacity in the London area expanded ninefold in the twenty years between 1888 to 1908. Most West-End butchers had refrigerators by the early 1890s but meat sold by street hawkers and in open-air markets continued to be the mainstay of working-class districts.

Interestingly, low-temperature storage tended not to be used for poultry and eggs; cellars were used instead, and for eggs chemical preservatives such as waterglass (sodium silicate), borax and formalin (formaldehyde).[78]

As chilling techniques developed, they were used to ship fruits from overseas. From the 1890s onwards, Californian peaches and pears began arriving in London in ships fitted with cool chambers – but the greatest trade was in apples. Other fruit, like bananas, ripened on the voyage, though a subsidised refrigerated service from

[74] Sources include Wikipedia http://www.wikipedia.org, the *History Magazine,* http://www.history-magazine.com, and the Canal Museum http://www.canalmuseum.org.uk
[75] Blain, B. (2006). *Melting Markets: The Rise and Decline of the Anglo-Norwegian Ice Trade, 1850-1920,* London School of Economics, Working Papers of the Global Economic History Network No. 20/06, http://www.lse.ac.uk/collections/economicHistory/GEHN/GEHNPDF/GEHNWP20-BB.pdf#search=%22history%20of%20refrigeration%20in%20the%20Uk%20domestically%20available%20%22
[76] Oddy, D. J. (2006). *Food quality in London, 1870-1938*, XIV International Economic History Congress, Helsinki, 2006, see http://www.helsinki.fi/iehc2006/papers1/Oddy.pdf
[77] Victorian Agriculture, University of Guelph, http://www.uoguelph.ca/ruralhistory/research/crowley/victorianAgriculture.html
[78] Oddy, D. J. (2006). *Food quality in London, 1870-1938*, XIV International Economic History Congress, Helsinki, 2006, see http://www.helsinki.fi/iehc2006/papers1/Oddy.pdf

Jamaica that began in 1901. With the increase in imports and the fall in prices, bananas were soon affordable for and very popular with the working classes.[79]

In short, from about the 1890s onwards, with the refinement of technology, mechanical refrigeration (at the commercial rather than the domestic level) began to be widely adopted although it was more enthusiastically taken up in some industry sectors than others. The requirements of the First World War gave further impetus to its use: with European production and trade much diminished, our need for food was met by big imports of frozen meat from the US. More stores were needed to hold these stocks, for both military and civilian use.[80]

By 1918, Britain had 1.1 million cubic metres of cold-store capacity and over 230 refrigerated ships.[81] Since then, of course, cold-storage capacity has increased dramatically: we now have about 10 million cubic metres of frozen storage capacity and an unknown volume for chilled goods.[82] According to Robert Heap, since around 1920 there has been approximately a twenty-fold growth world-wide growth in the shipping of refrigerated foodstuffs.[83]

What about domestic refrigerators? In the United States, the domestic refrigerator rapidly became a mainstream household fixture and by the late 1940s over 60% of households had a fridge.[84] In the UK however, take-up was much slower, and the domestic refrigerator remained the preserve of a few wealthy families. It was not until after the Second World War that refrigerators entered the mainstream market. Indeed, even as late as 1970, over 40% of the population still did not have a fridge, as Table 5 shows, while just a tiny minority owned a freezer.

Table 5: Ownership of refrigeration appliances, UK 1970-1995

	1970	**1980**	**1990**	**1995**
	Figures show % of households owning a refrigeration appliance			
Fridge-freezers	0	19	51	58
Refrigerators	58	72	52	46
Chest freezers	3	16	16	16
Upright freezers	0.5	11	21	22

Source: Table presented in *DECADE: Domestic Equipment and Carbon Dioxide Emissions – Transforming the UK Cold Market*, Environmental Change Unit, University of Oxford, 1997

In the Appendix to this report can be found vivid personal accounts of people growing up in the 1940s, 1950s and 1960s and of how and where they stored food.

Today, however, virtually every household owns some combination of fridge and freezer as Table 6 shows below.

[79] Oddy, D. J. (2006). *Food quality in London, 1870-1938*, XIV International Economic History Congress, Helsinki, 2006, see http://www.helsinki.fi/iehc2006/papers1/Oddy.pdf
[80] Thevenot, R. (1979). *A History of Refrigeration Throughout the World* , International Institute of Refrigeration, Paris
[81] Thevenot, R. (1979). *A History of Refrigeration Throughout the World* , International Institute of Refrigeration, Paris
[82] John Hutchings, Cold Storage and Distribution Federation, personal communication, 2006
[83] Robert Heap, Cambridge Refrigeration Technology, personal communication, November 2006
[84] Bowden, S. and Offer, A. (1994). Household appliances and the use of time: the United States and Britain since the 1920s, *Economic History Review*, XLVII, volume 4. pp. 725-748

Table 6: Ownership of refrigeration appliances, 2005

Year	Fridge-freezer	Chest freezer	Upright freezer	Fridge
	Figures show % of households owning a refrigeration appliance			
2005	**65**	**16.5**	**28.7**	**43**

Source: Table based on BNC08: *Assumptions underlying the energy projections for domestic cold appliances* Version 2.1, Market Transformation Programme, 18/09/06

The way we shop for, prepare and consume food is now predicated on the existence of the fridge and freezer, and for many of us it is hard to imagine living without them. How has this come about and how might our dependence on refrigeration develop in the coming years?

b. The growth in refrigeration dependence: contributing factors

This section looks briefly at how we managed before refrigeration became mainstream and what the advantages and disadvantages (from a food energy perspective) might be, or have been.

It explores the societal and economic developments that went hand in hand with the growth in refrigeration dependence. One should note that the extent to which these changes helped *engender* and to which they simply *reflected* our dependence upon refrigeration is not always clear, nor indeed would a clear distinction between cause and effect have been easy to make.

We then look at how our dependence on refrigeration might change in coming years, bearing in mind that trying to foretell the future is always risky and speculative.

The focus of most of this analysis is the early 20th century (and particularly post-1945 onwards) mainly because data sources for this period are more readily available. A full study would need to look properly at early societal patterns. While this section gives an overview of developments, the Appendix to this report, as highlighted, provides more concrete – and fascinating – insights into how food purchasing and storage was managed over the course of the last 50 or so years.

Growing incomes and working women

The economic growth which followed the Second World War meant that average incomes rose and more women entered the workforce. By 1971[85] nearly 60% of working-age women were economically active and of course the figure is higher still today at 74%. The result at the household level was more money to spend but less time to shop for food. Since shopping trips had to be made less frequently, this created a greater need for an effective means of longer-term safe food storage; prior to this, perishables could be bought daily. Implications of this are discussed below.

The post-war period was also characterised by a rapidly intensifying love affair with all things technological, including washing machines, televisions and so forth. With the growing ownership of televisions, and the introduction of commercial advertising, people were exposed to vigorous advertising not just of cold (and other) appliances,

[85] This is when the Labour Force Survey begins: see *Employment by age and sex – First Release dataset*, Office of National Statistics (data for earlier years are unfortunately not available): http://www.statistics.gov.uk/downloads/theme_labour/LMS_FR_HS/WebTable01.xls

but also of frozen food.[86] In the early days of the domestic freezer, the appliance was very expensive, owned by a tiny minority of the population and viewed largely as a handy means of storing seasonal gluts, whole sheep and so forth rather than for processed food. The vast majority of those initially buying frozen food would have stored it in the ice compartment of the fridge or bought and cooked it straight away. However, from about the 1970s onwards the UK saw the development and rapid expansion of the supermarket format and with it an extensive and reliable commercial infrastructure for storing and distributing frozen food. This, argue sociologists Shove and Southerton, proved the turning point for the freezer[87] and ownership levels rose rapidly.[88] As such the domestic freezer's ubiquity reflects not just the growth in national supermarkets and in national distribution systems, but it has also helped foster their further development. The freezer is now the final point in a smooth and temperature-controlled supply chain.

Marketing, supermarkets and the supply chain

How did all of the necessary infrastructure develop? Cox *et al*[89] argue that it was the frozen food manufacturers themselves who were key to the development and widespread uptake not just of the frozen foods themselves but also of the technological infrastructure. This in turn produced a snowballing effect; the technology prompted the development of further frozen goods, and vice versa.

The authors chart the development of Unilever, a pioneer in the frozen food industry, which towards the end of the Second World War had acquired the frozen food company Birds Eye. The company already owned subsidiaries producing fish, meat and vegetable products[90] and it already operated its own retail chain of fishmongers, MacFisheries. However, in order to make a success of the frozen food concept they needed to see higher levels of sales than could be managed via their stores alone. In the 1950s, very few shops had the freezers essential to storage of such food, so in 1957 Birds Eye persuaded two manufacturers of refrigerated equipment, Prestcold and Frigidaire, to design and market 'open-top' display cabinets for retail use.

In return, the company agreed to sell only to those retailers who installed such devices. Later, Birds Eye developed a policy of leasing refrigerated cabinets to some of its more important retail customers on condition that the equipment was used only for stocking Birds Eye products or other foods which were not direct rivals. Meanwhile consumers were bombarded with an array of Birds Eye brand propaganda and in-store inducements.

Thus, in pioneering the mass consumer market for frozen foodstuffs, Birds Eye actually needed to create the infrastructure before households could be offered the product in sufficient quantities to make manufacturing worthwhile.

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[86] Cox, H., Mowatt, S. and Prevezer, M. *From frozen fishfingers to chilled chicken tikka: Organisational responses to technical change in the late twentieth century*, Centre for International Business Studies, South Bank University, Paper 18-99, ISSN No. 1366-6290

[87] Although one observer (Robert Heap, Cambridge Refrigeration Technology, personal communication, December 2006) notes the fact that buying half a sheep, say, was cheaper than buying smaller cuts and therefore acted as a major incentive for purchasing a freezer

[88] Shove, E. and Southerton, D. Defrosting the Freezer: From Novelty to Convenience. A Narrative of Normalization, *Journal of Material Culture*, Vol. 5, No. 3, 301-319 (2000)

[89] Cox, H., Mowatt, S., and Prevezer, M. *From frozen fishfingers to chilled chicken tikka: Organisational responses to technical change in the late twentieth century*, Centre for International Business Studies, South Bank University, Paper 18-99, ISSN No. 1366-6290

[90] Including canned peas, potted and canned meats and so forth

As use of frozen food by caterers increased, smaller firms producing unbranded goods entered and so broadened the market. This increase encouraged other companies to enter the market, specialising in the provision of processing, storage and distribution services for these manufacturers. Some of the initial entrants, such as Christian Salvesen are still leaders in the field today. As the role of independent suppliers expanded, so the freezing capacity of these large storage and distribution companies began to rival those of the proprietary branded manufacturers.

The result of all this activity was an increase in customer sales and an increase in sales of domestic freezers in order to store all the foods that they were buying. In a further development, in 1968, the Bejam group opened a series of home freezer centres which combined the sale of home freezers with the retailing of bulk packs of frozen foods.

Hence the frozen food concept spawned the freezer infrastructure, which in turn catalysed further frozen food developments, which in turn extended the infrastructure. To put it more simply still, infrastructure generates further infrastructure. This observation may be worth bearing in mind when one considers how the food industry might further develop and what the energy implications of such developments might be.

One other technology that has gone hand in hand with the development of frozen food has been the microwave. Sociologists Shove and Southerton note that the freezer and the microwave enjoy a symbiotic relationship; the presence of one enables the use of the other. [91] While the microwave was initially marketed as an alternative to the conventional oven, sales did not really take off until it was positioned as an instant defrosting device for frozen food. Today microwave ownership stands at 83.5% of UK households.[92]

Interestingly, while the microwave's popularity was boosted considerably by the ubiquity of frozen foods, the microwave in turn has enabled and encouraged the development of a new (and rival) food development – the chilled ready meal. The microwave has also led to developments in new forms of microwave-safe packaging; another example of technology begetting technology, and infrastructure begetting infrastructure.

Cox *et al* note that the growth in ready meals has also been enabled by the retailers' information technology (IT) capacities. The short shelf life of chilled meals requires responsive logistics systems, which are themselves underpinned by and dependent on sophisticated IT. In short, the cold chain – and the environmental impacts arising from it – is about more than the refrigeration technology itself. It is about a nexus of transport, packaging, retail and IT infrastructure within which refrigeration technology is situated. How these and perhaps new technologies and infrastructures interact and develop in future years, and what the environmental implications might be, is impossible to say. It is likely, however, that new developments *will* arise. As such, 'straight' projections of the type undertaken by the MTP, above, while useful, are unlikely to tell the whole story.

[91] Pantzar, M., Shove, E., Southerton, D. and Strandbakken, P. (1999). *Configuring domestic technologies: the normalisation of freezers in Finland, Norway and the UK*. Paper distributed for the Consumption, *Everyday Life and Sustainability Summer School* 1999, Lancaster University http://www.lancs.ac.uk/fss/sociology/esf/freezers.htm

[92] BNCK05: Historical microwave oven use and options to increase usage in the future, version 1.2 Market Transformation Programme, May 2006

Food retailing and display

According to a study by Elsayed *et al* of Sheffield Hallam University, supermarkets, per square metre, are far more energy intensive than other food shops.[93] It may of course be possible that if one were to measure energy use per volume of *food turnover*, the conclusion would be different. Whatever the balance, it is clear that refrigeration accounts for a large proportion of supermarkets' intensive energy use. The multiple retailer Waitrose for example calculates that over 65% of its energy is used to refrigerate food,[94] while Sainsbury's states that refrigeration is the main use of energy in stores.[95] The Sheffield Hallam study itself finds that refrigeration accounts for 42% of store carbon emissions (electricity and gas combined).[96] This heavy use of refrigeration reflects both the type of foods that supermarkets sell and the decisions made as to whether or not they need to be displayed in a refrigerated unit. Meat is arguably one product that really does need to be stored cool and if the Sheffield Hallam data for butchers' shops and for supermarkets are compared, one finds that both use fairly similar amounts of refrigeration per square metre. However, when it comes to fruit and vegetables it is interesting to note that greengrocers use almost no refrigeration whereas in supermarkets, many fruits and vegetables are displayed in refrigerated cabinets. Multiple retailer Marks & Spencer takes this tendency to refrigerate to its most extreme – a walk around one of its stores showed that not only the pre-cut foods, but even whole fruits such as pineapples and apples are displayed refrigerated. This is not (yet) the case with the other multiples.

Most supermarkets are now open from Monday to Saturday from 8am to 10pm, and are open for much of Sunday too. Some larger stores are even open for 24 hours. This means that there is relatively little opportunity for the lights to be dimmed and the covers to be put on refrigerated display cabinets, both energy-saving measures.[97] The consequences are inevitably more energy use.

It may also be the case that the availability of more brands and more variations on particular product types means that more (refrigerated) shelf space is required on which to display them. In other words, more choice leads to larger stores and a larger chilled food area, which in turn leads to greater refrigeration requirements. The issue of choice, variety and environmental impact is discussed further below.

Shopping patterns

How often we shop for food and how much we buy at any one time will clearly have a bearing on refrigeration needs. Perishable food bought to be eaten within a day of purchase may not need refrigerating, in contrast with perishable food that is bought to last the week. And if many days' worth of perishable food is being bought, then a big fridge will be needed to contain it all.

Up until the 1970s food was purchased daily or at least very frequently, usually by women. People either went to the shops to buy food or received food deliveries (see below and Appendix). However, the rise in female employment highlighted above,

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[93] Elsayed, M. A., Grant, J.F., Mortimer N. D. (2002). *Energy use in the United Kingdom: non-domestic building stock: 2002 catalogue of results*. Final report for the Global Atmosphere Division of Defra. Contract reference number EPG 1/1/53 Report reference number SCP 4/12

[94] See http://www.johnlewispartnership.co.uk/Display.aspx?MasterId=81f00253-1639-4749-a590-d2cd32540b62&NavigationId=613

[95] See http://www.jsainsburys.co.uk/files/reports/cr2005/index.asp?pageid=59

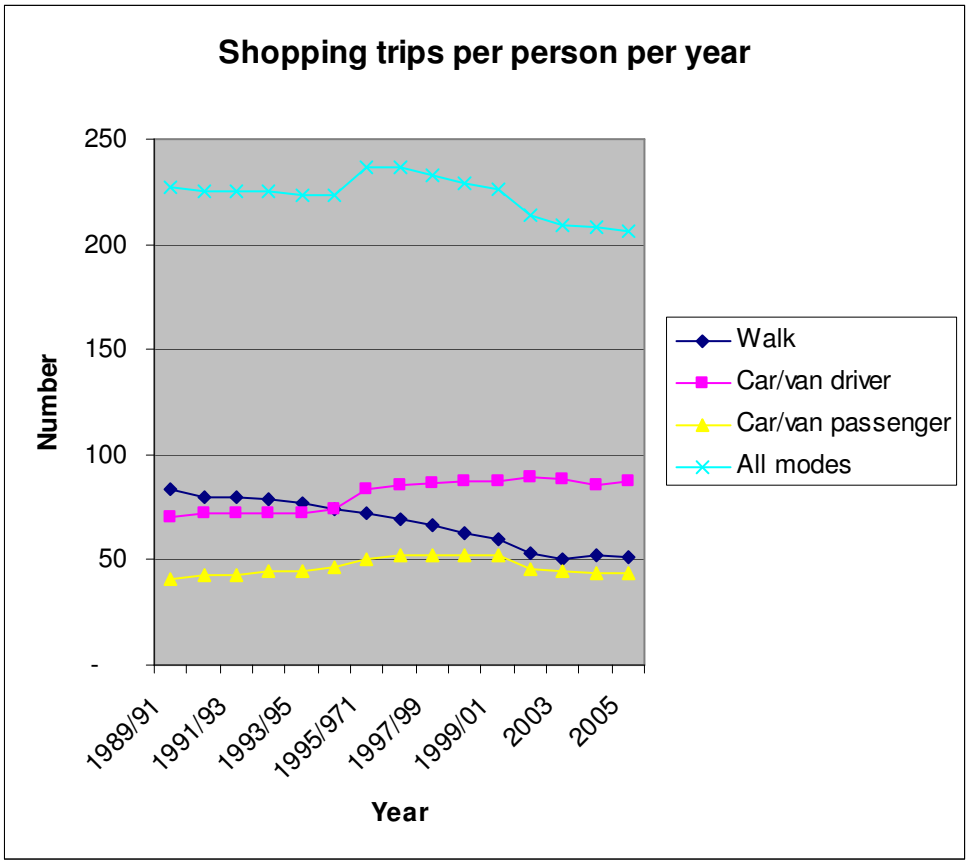
[96] The figure includes 'catering' but this is likely to be relatively unimportant

[97] The argument has been put that the lights will in any case be on and the refrigeration display cabinets open to allow to staff to restock. However, it is perfectly possible for shelves to be stocked during the course of a shorter day

together with the growing dominance of the supermarket chains, led to a shift to the weekly, and by now car-dependent shop.

How have trends developed in recent years and what might we expect to see in coming years? Data on shopping patterns going back to the immediate post-war period are unfortunately not available but more recent data from 1989[98] show that while the overall number of shopping trips has declined, the number undertaken by car has increased, as has the average distance travelled.

Figure 3: Shopping trips per person per year



Source: Department for Transport
Note: from 1995/97 onwards the reported numbers are positively weighted to allow for non-response and for the observed tendency for respondents to record fewer trips towards the end of their survey week (known as 'drop-off'). If years prior to this date were also weighted (which they are not in this table) then the trends would be more pronounced. That is, the decline in foot-based trips would be even steeper, as would the decline in overall trips. The number of car-based trips would be more level.

Data on *food*-related shopping trips are only available from 1998 but they tell a subtly different story. The number of food trips is actually slightly increasing while the growth in trip length is possibly a little more muted.

[98] Department for Transport, personal communication October-November 2006

Figure 4: Average trip length for food shopping by mode

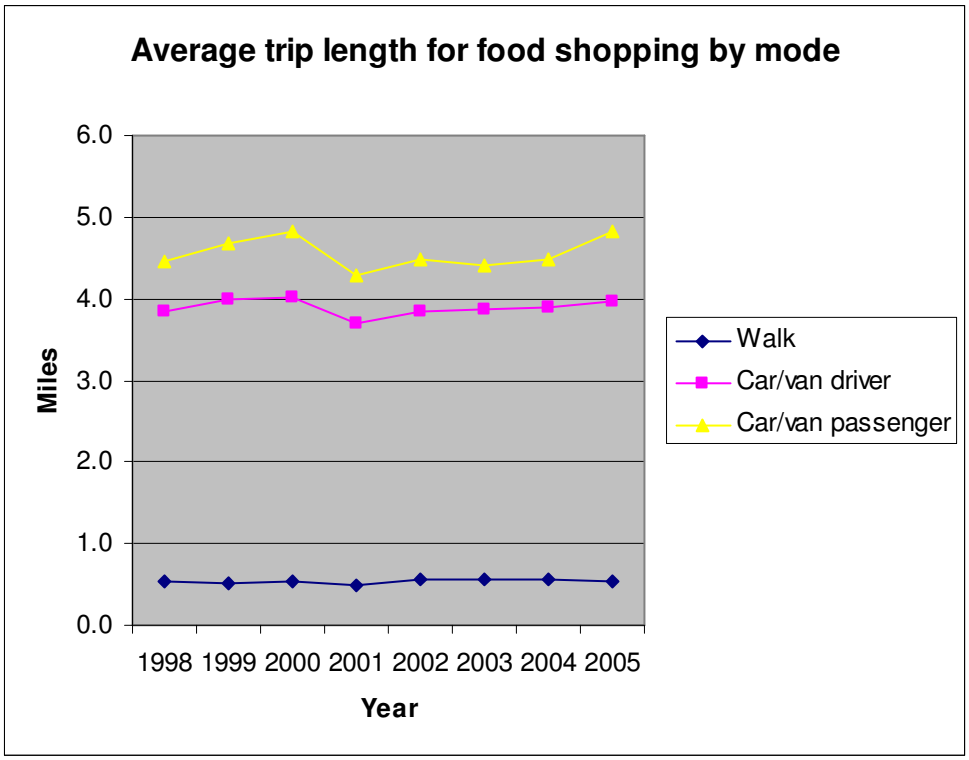
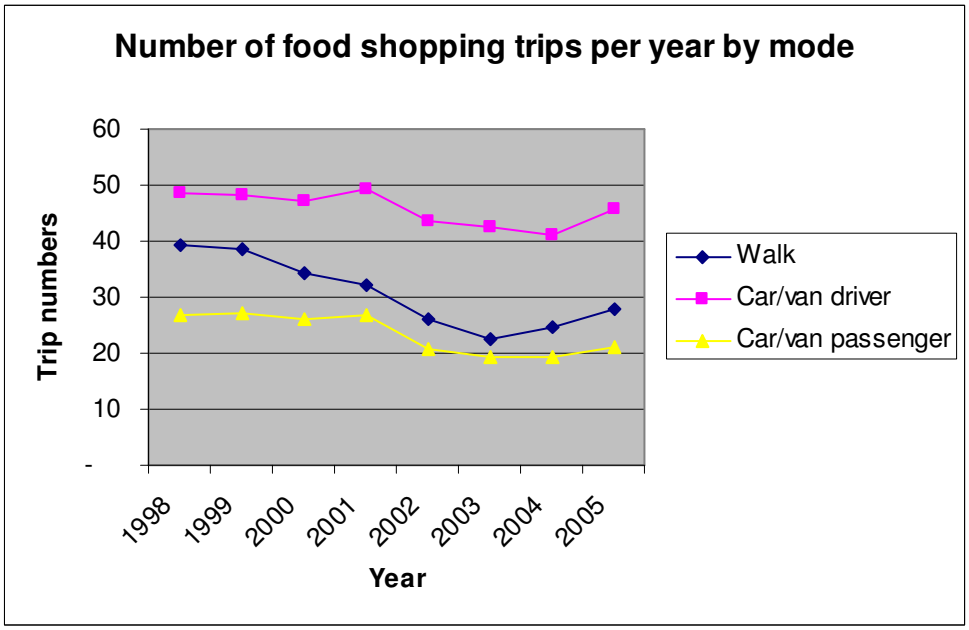


Figure 5: Number of food shopping trips per year by mode



The National Travel Survey data are based on a representative national-level sample of people. This will include the vast majority of people who live in urban areas as well as those in rural and peri-urban areas where car dependency is even higher than it is in cities. The last few years have seen a trend in this country (in contrast to almost everywhere else in the world) for people, most commonly affluent and older, to move

back into suburban and rural areas.[99] With the demise of local village shops these rural dwellers are dependent on car-based travel. If we were to look only at *urban* dwellers we might actually see a stronger trend towards more frequent shopping trips and shorter distances travelled.

This is borne out by a study of long-term changes in shopping patterns in Portsmouth,[100] a city which reflects national demographics. This study finds that the proportion of people shopping twice a week or more frequently rose from 17.5% in 1980 to 40.7% in 2002. The authors point out that this has clearly been aided by the growth in the number of supermarket stores near to where people live and work.

The study findings also show that the proportion of trips taken by car fell from 95% in 1980 to 89.5% in 2002, in contrast with the National Travel Study data where the proportion remained constant. Note that the Portsmouth study looks at changes over a long period of time (20 or so years) whereas the National Travel Survey follows food-related travel for a period of only six years, so the two may not be comparable.

Interestingly the Portsmouth study also reveals a growth in the number of very short food-shopping trips (less than five minutes travel time to store) and a small rise in the number of very long ones (more than 30 minutes – and still constituting only 3% of all food trips). The number of food trips made on the way to or from home has stayed the same; the number made coming back from work has actually declined. Most of the new trips are made when coming back from 'other destinations' – a definition that excludes other shops. Perhaps this means that on the way back from work people go on to do other leisure activities and only then make their way home via the shops.

One other revealing finding from the Portsmouth study is that people buy a smaller proportion of the overall food they need at each shopping trip. This is unsurprising – if they are shopping more frequently they are likely to be buying smaller quantities.

The authors of the Portsmouth study suggest that these changes may be due to a number of factors, including:

'…*more hectic lifestyles and a greater proportion of food being sold that is 'fresh', chilled, or frozen rather than dry packaged, thus necessitating more frequent shopping. We might speculate too, that this shift masks other important changes in shopping habits, such as the reduction in the number of small, local stores over the last thirty years. This may have forced customers into using the larger stores more frequently for 'top-up' shopping as well as their main primary shop.*'[101]

Note that the study looks only at the major store developments and did not look specifically at the growth in the multiples' smaller store formats.

With the growth in single-person living and perhaps a less planned food shopping culture, future years may see this tendency to shop more frequently continue.

What does all this mean for refrigeration dependence? While this in theory suggests that people could make do with less refrigeration since the turnover of food will be

[99] Office for National Statistics data 2001 http://www.statistics.gov.uk/cci/nugget.asp?id=1310 – note that more recent data are not available

[100] Clarke, I., Hallsworth, A., Jackson, P., Kervenoael, R., Aguila, R. P., Kirkup, M. (2006). Retail restructuring and consumer choice 1. Long-term local changes in consumer behaviour: Portsmouth, 1980-2002 *Environment and Planning A* 2006, volume 38, pp. 25-46

[101] Elsewhere the paper notes that the concentration of multiples has increased, from three in the early 1980s to seven in 2002

more frequent (as in the 1950s), in practice the opposite is likely to be the case. For a start, much of the growth in food purchased is of the chilled ready meals and pre-washed salads varieties, together with other refrigeration-dependent foods. Whether this development is driven by consumer preferences (for, say, convenience) or whether by an industry that has invested heavily in the necessary technology and infrastructure is a matter for debate.

Another change in our shopping patterns is the almost total demise of daily food deliveries including bread, meat, fish, vegetables and, most notably, milk. These, as we have noted, have been driven by larger-scale changes in the economy, including the increase in female employment and the growing dominance of the supermarkets.

When daily deliveries were the norm, there was less need for households to own a refrigerator (see Appendix). The onus of refrigeration was pushed higher up the supply chain and placed on manufacturers and distributors. Indeed in her study of Dutch domestic architecture, the anthropologist Irene Cieraad highlights this relationship between deliveries and daily refrigeration needs.[102] She notes that post-war sales of refrigerators were very low in the Netherlands, where daily deliveries were the norm and this is in contrast with Finland where the home delivery system did not exist, and where sales of refrigerators were much higher.

In the UK the daily doorstep milk delivery was the norm even as late as the 1980s but thereafter declined steeply. In 1980, doorstep milk deliveries represented almost 90 per cent of household milk sales, but by 2002 this share had dropped to just over 20 per cent.[103] As Table 5 shows, by the 1980s most people had a fridge anyway and so by this stage, the daily delivery was not needed to ensure freshness. With a fridge, milk could be stored for days. Since milk was sold more cheaply in the supermarkets that people were already visiting, it made sense to buy perishables at the same time.

Another factor in the decline of the daily delivery was the growing number of women entering the workforce. If, as Cieraad points out, there was no-one at home to receive deliveries, the delivery could not be made. With milk, which was typically delivered very early in the morning, this was not such an issue but it could have played a part in the decline in bread and other deliveries which were still common in the 1950s and 1960s, as some of the personal accounts in the Appendix show.

Now, we are again seeing a rise in the popularity of home deliveries, mediated via the internet. The difference this time is that the foods come from one retailer only and so the householder needs to ensure he/she is in for just one delivery, just once a week. In order to enable deliveries to be made even when no-one is at home, the industry has been exploring the possibility of installing the infrastructure such as secure boxes to enable drops to be made even when the customer is out. A study conducted by Cairns, from UCL's Centre for Transport Studies,[104] highlights the various products have been developed. So far such ideas have not really taken off since they are expensive to install and they raise the question of who pays for it: the delivering retail company, or the customer? Some commentators argue that the priority is to incorporate such units when new housing is built, since the marginal costs of adding such features is less. Some of the designs tend to rely on insulation to keep foods

[102] *The Milkman always Rings Twice… The Effects of Changed Provisioning on Dutch Domestic Architecture*, Irene Cieraad, forthcoming
[103] *Arla Foods amba / Express Dairies: Merger Inquiry*, Competition Commission, August 2003 http://www.competition-commission.gov.uk/rep_pub/reports/2003/fulltext/483c3.pdf accessed 23 October 2006
[104] Cairns, S. (2005). Delivering Supermarket Shopping: More or Less Traffic? *Transport Reviews*, Vol. 25, No. 1, 51–84

cool or cold, but one might surmise that if these boxes are incorporated into new building designs, they might well have refrigerated compartments.

Changes in household design

It would be interesting to go back several centuries and examine how and where domestic space was allocated to food storage, how this differed by social class and between rural and urban areas and of course how well such arrangements worked. This would require a fairly extensive study; the discussion here looks mostly at arrangements from the early 20th century onwards, and merely touches upon some of the issues involved.

As regards the Victorian era, a feature of many middle- and upper-class houses was the existence of a cooler separate room for food storage in the home – a larder. Most middle-class Victorian homes would have had one, and perhaps a scullery too for washing up. The ubiquity of such a room can be inferred from period housing plans and specifications, and from visits to homes open to the public. However the situation was likely to have been very different for the poor, who tended to live in cramped, inadequate accommodation. Geographer Peter Atkins[105] cites a study which found that of 2,669 houses inspected in Colchester from 1905 to 1908, 92.8% had no larder. Many of the poor did not have the facilities to cook, let alone store food, and subsisted largely on sweet tea, bread and butter, supplemented – where cooking facilities were available – with potatoes and the occasional cheap cut of meat.[106]

That better standards for the poor were important and, as part of that, that a place to store food was desirable, is evidenced by building and design specifications of social reformers and Government advisory bodies. Plans for Joseph Rowntree's model 'garden village' for example (work began in 1902), designed by master planners Raymond Unwin and Barry Parker, show that houses were designed with larders.[107]

A few years later on, the Tudor Walters Report of 1918[108] recommended that every house should contain, among other things, a scullery and a larder.[109] In practice many private house builders built homes with larders little bigger than cupboards.[110] Nevertheless the fact that even the cost-cutters of the building world included a larder of sorts in their designs suggests that such a space was considered essential.

The post World War Two era saw a boom in house building and between 1948 and 1958 one household in six moved to a new-build house or flat.[111] Judging from the accounts of those growing up in them (see Appendix), larders were still a feature of these new-build homes, and were used.[112]

[105] Atkins, P. J. (1992). White Poison? The Social Consequences of Milk Consumption 1850-1930, *Social History of Medicine*) citing W. G. Savage, *Milk and the Public Health* (London, 1912), p. 271
[106] Spencer, C. *British Food: An extraordinary thousand years of history.* Grub Street, London, 2002
[107] See http://www.jrf.org.uk/centenary/homes.html
[108] Often called the 'homes fit for heroes' report, this was commissioned by the Government in 1917 to set standards and to produce model plans and specifications for the building industry in preparation for the house-building programme which was to start at the end of the First World War.
[109] See http://www.homeownersales.co.uk/1900.html
[110] See http://www.pre-war-housing.org.uk/internal-planning-services-and-fittings.htm
[111] Lyon P, Colquhoun A, Kinney D. (2004). UK food shopping in the 1950s: the social context of customer loyalty, International Journal of Consumer Studies, 28, 1, pp. 28–39
[112] Personal communications with people living and growing up in 1950s-built houses

However, in 1961 Parker Morris[113] published his Government-commissioned report, *Homes for Today and Tomorrow*. This set new standards for social housing that sought to meet the changing needs of the modern family. In addition to generous minimum space standards,[114] Parker Morris concluded that there should be more living and circulation space, mainly split into an area for quiet and leisure activity, and an area for eating; the latter could be an enlargement of the kitchen. The formal Sunday-best parlour no longer featured. Tellingly, nor does the larder.[115] The report also placed great emphasis upon better, whole-home heating (in 1970 only 31% of homes had central heating).[116] This, it has been argued,[117] was the standard which helped de-specialise the hitherto separate functions of the various rooms. If all rooms are to be used at all times, then they all need to be warm.

Homes with central heating and hence higher general ambient temperatures, with little demarcation between cooking and living areas and with no provision for a separate food storage area are likely to pose problems when it comes to keeping food cool. Whether the Parker Morris standards took for granted the widespread ownership of the refrigerator or whether they indirectly helped spur on the rise in uptake is unclear. Another look at the data in Table 5 shows that it was not until about 1968 that 50% of UK households owned a fridge. Low-income groups who were eligible for social housing were perhaps those least likely to be able to afford one but, in the absence of alternative arrangements, the new housing design might have rendered its purchase necessary. On the other hand this correlation may be far too simplistic a conclusion – the role of marketing and the changing cultural and economic factors also played a very important part, as discussed above.

It is of course also the case that most of the population did *not* live in new-build accommodation but in older homes that were less likely to have central heating and more likely to have separate food storage space. One might thus merely raise the possibility that changes in our living arrangements helped contribute to a situation which was favourable to the uptake of the domestic refrigerator.[118]

It is worth noting that according to some estimates, up to 10 million new homes will need to be built by 2050 to meet projected growth in housing demand.[119] These new homes will almost certainly follow the trend towards 'integrated' living and will take for granted the presence of a fridge or freezer. It is also worth noting that where kitchen storage space is limited the fridge also serves as a handy additional cupboard.

Changes in ambient domestic temperatures

In order to understand how we have come to be so dependent on refrigeration it is also helpful to look at trends in domestic ambient heating. As already highlighted, the warmer the home, the more likely the food is, if unrefrigerated, to spoil.

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[113] Parker Morris (1961). *Homes for Today and Tomorrow* (The Parker Morris Report). London: Ministry of Housing & Local Government, HMSO

[114] Ironically, homes built for private buyers were far less spacious

[115] Brierley, E. S. (2004). The Social and Environmental influence of the Parker Morris Report, *Journal of Applied Psychology* (ISSN 1454-8062)

[116] *Domestic Energy Factfile 2003*, Building Research Establishment, 2003, Bracknell, UK. See http://projects.bre.co.uk/factfile/BR457prtnew.pdf

[117] Brierley, E. S. (2004) The Social and Environmental influence of the Parker Morris Report, *Journal of Applied Psychology* (ISSN 1454-8062)

[118] Bowden, S. and Offer, A. (1994). Household appliances and the use of time: the United States and Britain since the 1920s, *Economic History Review*, XLVII, volume 4. pp. 725-748

[119] Boardman, B., Darby, S., Killip, G., Hinnells, M., Jardine, C. N., Palmer, J and Sinden, G. (2005). *40% House*, Environmental Change Institute, University of Oxford

Information on household ambient temperatures in past times are not available – records only begin in 1970.[120] All that can be said is that before the advent of central heating systems, heating (from a wood or coal fire and later a gas fire or radiator), will have been localised, and probably confined to the living areas.

Between 1970 (when records start) and today, it appears that average internal temperatures have risen considerably. Figures by the Building Research Establishment show an increase in mean internal temperature of 6°C between 1970 and 2004, from around 12°C to 18°C. The UCL researcher Fawcett (2005)[121] pulls together results from several studies which show similar trends. Note that the figures given are the mean temperature for all rooms; the living area (which, as noted, may also be the kitchen) is normally a couple of degrees warmer. In all then, the average temperature of today's kitchen is likely to be much warmer than it was in the past.

Some evidence suggests that the average internal temperatures are continuing to increase. For example, Fawcett cites research showing that a substantial proportion of Swedish homes are heated to as high as 23°C. A UK telephone survey of 1,036 randomly sampled households undertaken for the Energy Saving Trust[122] found that nearly half of all homes have their thermostats set above the recommended 18-21°C (presumably this means they set it above 21°C). Indeed 19% set their temperatures above 25°C and, interestingly, 25-34 year olds set their temperatures higher, on average, than all age groups. The behaviour of the under 25s was not recorded. One would assume that this is because most will either be living with their parents or in some form of college accommodation and so will have less direct control of their thermostats. Once this younger age group starts to live independently it is very probable they will follow the behaviour patterns of the 25-34 year olds.

Not all research however suggests that average temperatures will continue to rise. Another study[123] followed up an initial piece of research on internal temperatures of energy-efficient homes in Milton Keynes in 1989-1990. It compared these temperatures with what they found to be the average in 2005, and actually found there to be no change (although it should be borne in mind that since the homes were energy efficient the study findings may not be applicable to the 'average' UK home). Interestingly, from the perspective of general energy use, they also found that the majority of people in 2005 reported keeping bedroom windows open at night.[124] The authors therefore suggest that while *temperatures* may have stabilised, energy consumption could continue to rise if ventilation rates increase. In other words, the definition of comfort continues to evolve in increasingly energy-intensive directions.

Changing food tastes

General trends

To what extent are the foods we now like to eat different from, and more refrigeration-dependent, than the foods we ate fifty years ago, when domestic refrigerators first entered the UK market?

[120] Utley, J. I., Shorrock, L. D. (2006). *Domestic Energy Factfile: Owner-occupied, local authority, private rented & registered social landlord homes*, Defra, Building Research Establishment, Energy Saving Trust
[121] Fawcett, T. (2005). Investigating carbon rationing as a policy for reducing carbon dioxide emissions from UK household energy use, Doctoral Thesis, University College London
[122] 17 million UK homes exposed to winter 'gremlins'/ Energy Saving Trust/ICM Poll, 18 January 2006
[123] Summerfield, A. J., Bruhns, H. R., Caeiro, J. A., Lowe, R. J., Steadman, J. P., Oreszczyn, T. *Milton Keynes Energy Park Revisited: Changes in internal temperatures*. Study for the Carbon Reduction in Buildings Consortium, funded by the Carbon Trust and Engineering and Physical Sciences Research Council
[124] The study does not make clear whether (a) this was not the case in 1990 or (b) that this issue was simply not looked at in the original survey. The implication from the text appears to be (a)

Unfortunately there are no Government records of household purchases of foods in the 1950s. However it is clear that with the end of food rationing in 1954[125] and the introduction of the Common Agricultural Policy (with its emphasis on increasing productivity), the availability of refrigeration-dependent animal products such as butter, milk and meat, increased. Historians of the 1950s will also point to the dominance of tinned food; a useful and by then well-established means of storing food, unrefrigerated, almost indefinitely. There is also frequent mention of meat and dairy products in the personal accounts set out in the Appendix.

From 1974 onwards (by which time well over half the population owned a fridge), Government began to compile data on food purchasing habits.[126] Comparing foods we bought then with what we buy now, thirty years on, reveals interesting changes.

Table 7 shows details of trends in per capita weekly consumption of those foods that today one might normally store in the fridge. These include foods such as meat, fish, cheese and vegetables. These figures include chilled and processed foods: for example a meat-based ready meal will be included in the 'processed meat' category.

Store-cupboard ingredients such as cereals and tinned food are excluded from the table. The same goes for jams, condiments and eggs, even though today many people do keep these (particularly eggs) in the fridge. Since many fruits are often kept unrefrigerated in a bowl, only figures for soft fruit purchases are presented.

Table 7: Trends in consumption of temperature-sensitive foods (g or ml/person/week)

	1974	**1984**	**1994**	**2004/5**
Milk and cream (excluding dried)	2893	2414	2202	1975
Cheese	105	109	106	110
Carcass meat	393	348	250	229
Non-carcass meat /meat products (excluding canned and takeaway)	570	667	677	709
Fish (excluding canned)	105	119	121	119
All fats (excluding cooking oils*)	294	269	183	127
Fresh green vegetables	364	318	254	225
Other fresh vegetables	404	447	480	536
Temperature-sensitive processed vegetables	166	220	341	323
Ice-creams and frozen fruits	46	103	127	178
Pure fruit juices	34	167	267	280
Unconcentrated soft drinks	0	0	704	1071
Fresh soft fruit	44	102	123	177
Quiches, pizzas and flans	2	1	4	1
Alcoholic drinks minus liqueurs, spirits*, etc	0	0	505	712
TOTAL	**5420**	**5284**	**6344**	**6772**
TOTAL EXCLUDING DRINKS	**5386**	**5117**	**4868**	**4709**

Source: UK household purchased quantities of food and drink – 1974-2004-5, Family Food 2004-5, Defra http://statistics.defra.gov.uk/esg/publications/efs/datasets/default.asp

Note: the table above aggregates individual food items recorded in National Food Survey data. All canned food and takeaway foods stuffs are excluded from the figures given in the table

[125] Lyon, P., Colquhoun, A., Kinney, D. (2004). UK food shopping in the 1950s: The social context of customer loyalty, International Journal of Consumer Studies, 28, 1, pp. 28-39

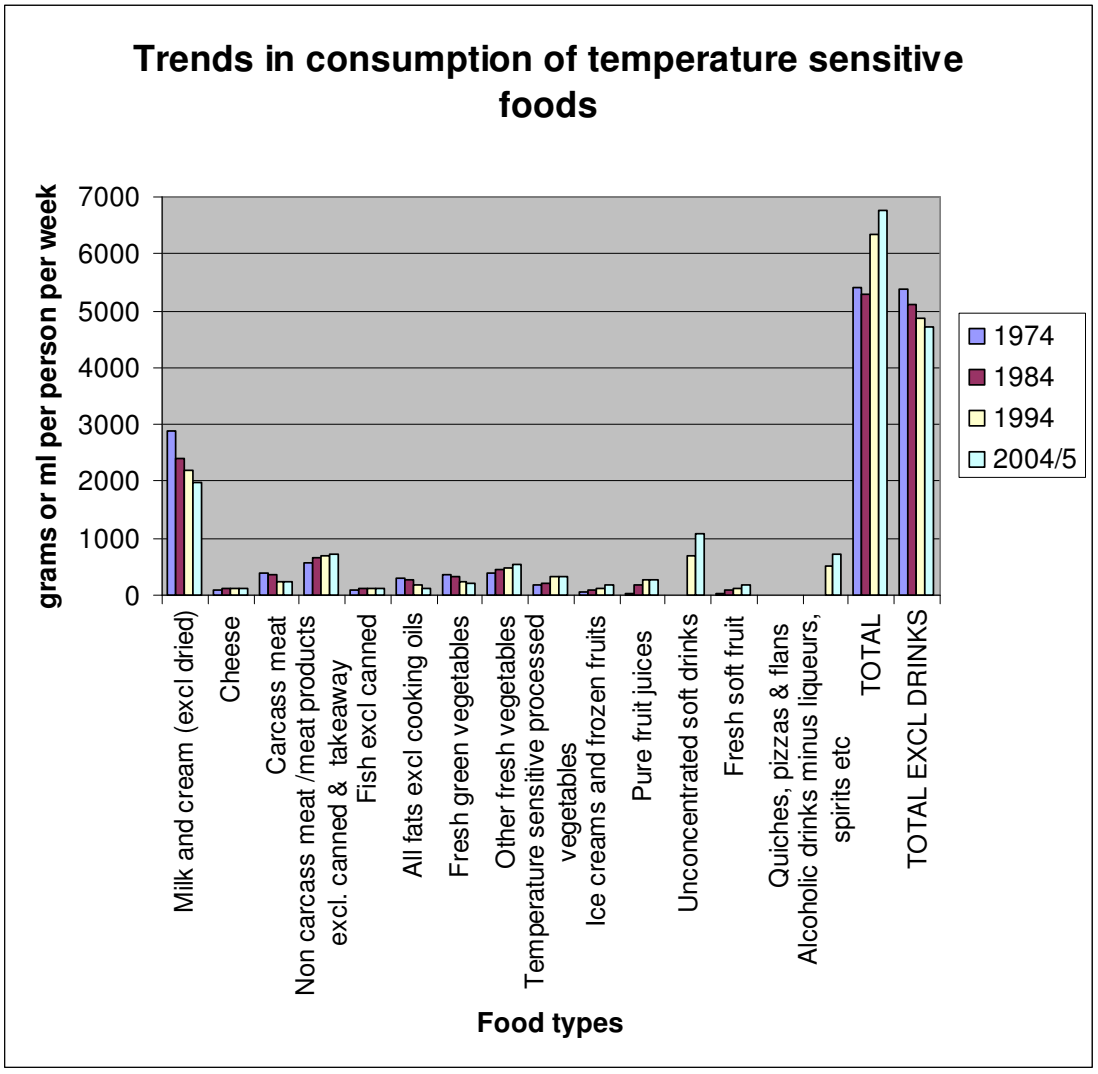
[126] Note that this is not the same as our actual consumption of these foods, which are more accurately reflected in the *National Diet and Nutrition Survey* held by the Food Standards Agency. However the emphasis on purchases is appropriate here because on the whole people do bring the food they buy home and store it, even if they end up throwing it away

above. Occasionally a zero value does not indicate no consumption but simply the fact that no records were made of that food at the time.

*Cooking oils, liqueurs and spirits are excluded as they tend to be stored at ambient temperature.

Figure 6 illustrates in graph form how trends have changed over time. The most significant development has been the growth in purchases of alcoholic and soft drinks, and of fruit juices, many of which are consumed chilled. However since many of these drinks may be stored at room temperature and then refrigerated just an hour or two before needed, the totals are also recalculated to exclude them. Counter-intuitively, once these drinks are excluded, our consumption of temperature-sensitive foods appears to have actually declined.

Figure 6: Trends in consumption of temperature-sensitive foods



Source: *Family Food*, Defra 1974-2004/5

This is perhaps a surprising conclusion. However a closer look at the National Food Survey data reveals a somewhat different picture.

The main reason for the apparent decline in our consumption[127] of refrigeration-dependent foods is the fact that we now do not drink as much milk as we did thirty years ago. Milk is an interesting case since, as highlighted above, it used in any case to be delivered daily and hence there was less need for refrigeration. If fresh milk is excluded from the figures the trends in refrigeration-dependent foods go up again.

As for drinks, both alcoholic and non-alcoholic, while many drinks are stored at ambient temperature and are only refrigerated a little while before they are consumed (hence the reason for recalculating the figures above) this is not true of all drinks. Many drinks are retailed already cold, in chiller cabinets, meaning refrigeration energy is being used at the retail outlet. Some of them may be consumed immediately. With other chilled drinks not intended for immediate consumption it may be (judging from personal experience) that because they are already cold they tend to be put in the fridge 'to keep the cold in', as it were, even if they are not to be consumed for a while. It is also the case that within the juice category, recent years have seen strong growth in sales of 'premium' chilled juices, requiring refrigeration at all stages. In 2004 these accounted for 34% by volume of all pure fruit juices sold, up from 28% in 2002.[128]

A closer look at the National Food Survey data for green vegetables also reveals interesting trends. While we may eat fewer green vegetables now than in 1974, within this category, certain types have grown at the expense of others. In particular, our consumption of highly perishable, refrigeration-dependent lettuces and leafy salads has grown by 72%. In the 'other fresh vegetables' category, figures for mushrooms, cucumbers and other more temperature-sensitive foods tell a similar story.

The last thirty years have also seen a strong growth in fruit sales – a 56% increase between 1974 and 2004. Of course, many of us do not store all fruits in the refrigerator; what is more, a fairly staggering three-quarters of the increase is accounted for by the ever-popular, but never refrigerated banana.[129,130]

This said, the mix of fruits we eat now, compared with 1974 does suggest a growing preference for the more temperature-sensitive types of fruit (or at least fruit that is perceived to be temperature sensitive). There has, for example, been a decline in our purchases of those fruit-bowl mainstays, the apple and the orange. By contrast, sales of stone fruit and grapes (which are often if not always refrigerated) have risen from 38g per person per week to 115g per person per week. The rise in spending on soft fruits such as berry fruits is already recorded in Table 7 above.

Potatoes do not feature in Table 7 or Figure 6 above. However, while our consumption of fresh potatoes has more than halved between 1974 and 2004, of those potatoes that we do eat, new and baby potatoes have become more popular. These tend to be the ones that are stored refrigerated in supermarket display cabinets and sometimes even at home.

Of course the decision to store a can of drink or some fruit in the fridge will not make a difference to energy use if the fridge is already there. However, the point being made here is that as more and more people choose to buy the sorts of foods that are intrinsically perishable and as the definition of what foods require refrigerating changes, so we have seen a move towards the purchase first of fridges and then of

[127] Strictly speaking we should be talking here about purchases rather than consumption since this survey is a record of spending not of eating.
[128] *Fruit Juice and Juice Drinks* – UK, November 2004, Mintel
[129] *UK Purchased quantities of household food & drink 1974 to 2004-05,* National Food Survey http://statistics.defra.gov.uk/esg/publications/efs/datasets/efscons.xls
[130] At least at the domestic stage

larger fridges to accommodate all this food. This trend has already been well noted,[131] going some way to explain how and why our dependence on refrigeration has grown.

It is very important to emphasise too that the domestic refrigerator is only the final stage in the cold chain. Today all fruits and vegetables, including those that we might not store refrigerated at home (potatoes, onions, bananas) are temperature controlled at most other stages in the supply chain. In other words, a focus only on the domestic stage obscures the fact that temperature control earlier on in the supply chain is now universal for all fresh and some other products. This would not have been the case for all foods in, say, the 1950s. At that time supply chains tended to be more local and there was thus less need for refrigeration. This said, the combination of refrigeration and controlled atmosphere for storage of apples and pears was well established before World War Two; milk would have been chilled on-farm in most cases, and imported products such as bananas and meat will also have been temperature controlled. The benefits of refrigeration will have included less food spoilage and waste, although, as Section 5 discusses, the relationship between cold storage and waste is more complex than it at first appears.

The MTP trends, discussed above, suggest that the move towards buying ever larger fridges has now peaked, helped by the fact that with more of the population living alone and eating out more, there is less of a need for large fridges. The Energy Saving Trust however notes a continuing move towards larger American-style fridges. Moreover, very recent years have seen a growing interest in health issues and this has been reflected by a slight increase in fruit and vegetable consumption.[132] If this trend continues, married as it is with our growing demand for convenience (that is, for foods in pre-prepared, ready-assembled and hence refrigerated form) it may be that the MTP's expectations are overly optimistic.

It is also important to emphasise that although the total quantities we purchase to eat at home have not (excluding drinks) risen, there has at the same time been a substantial growth in eating out. Adding the per capita in-home and out-of-home purchases together, the total weight of purchases in 1974 and 2004/5 are roughly the same.[133] Since we are now less physically active as a society, our calorific needs have reduced – we don't need to eat as much as we did in the 1970s. If nevertheless we are buying the same quantities of food then we may not just be getting fatter (which we are) but we may also be wasting more food; an issue that is discussed further in Section 5.

The growth in eating out merits further investigation, since more eating out leads to more catering outlets, which in turn means more commercial cold-storage equipment. The MTP projections assume that there will be a growth in sales of commercial refrigeration equipment based on current trajectories but they do not necessarily take into account trends in the sorts of things we choose to eat when we eat out. Out-of-home consumption data are only available from 2001 onwards[134] but they show that spending here is increasing more rapidly than spending on in-home food and drink: compare a 1.7% rise for the in-home, with 3% for out-of-home spending between

[131] Boardman, B. (2004). *Achieving energy efficiency through product policy: the UK experience*. Environmental Science and Policy 7(3), pp. 165-176

[132] *UK Purchases and Expenditure on Food and Drink and derived Energy and Nutrient Intakes in 2004-05*, Defra, December 2005. See http://statistics.defra.gov.uk/esg/statnot/efsstatsnotDec05.pdf

[133] UK household-purchased quantities of food and drink – 1974-2004/5, Family Food 2004/5, Defra. See http://statistics.defra.gov.uk/esg/publications/efs/datasets/default.asp

[134] *UK Purchases and Expenditure on Food and Drink and derived Energy and Nutrient Intakes in 2004-05*, Defra, December 2005. See http://statistics.defra.gov.uk/esg/statnot/efsstatsnotDec05.pdf

2001/2 and 2004/5. Note that for both in-home and out-of-home spending, figures are not adjusted for inflation so the increase in both cases will be lower than it appears.

Slightly confusingly though, if one looks at the trends in eating out *by weight* (grams/ml) and by calorie intake there actually appears to be a decline. Intakes of food eaten at home have also declined (as highlighted above) but to a much lesser extent. In other words, the rate of food spending out of the home is increasing more rapidly than for the in-home spending rate, but the out-of-home quantities consumed are declining more rapidly than for in-home.

This is slightly odd. This may simply reflect the fact that Defra has only recently (since 2001/2) started to collect out-of-home food data and is still adjusting its methodology. Or perhaps the increase in spending concurrent with a decline in the quantity eaten reflects a shift towards eating at more expensive establishments. Or else it might have something to do with our general tendency to under-report our food intake. It has been well known for some time that people tend to under-report the amount of food they consume.[135,136] There is also a fair body of research[137] suggesting that fat people tend to under-report more than thin people. It may be, then, that as we get fatter as a nation, we are also increasing the amount by which we under-report. One might also speculate that the very high media attention paid in the last two years in particular to the 'obesity crisis' has made people more self-conscious about what they eat, even – given some of the moralistic hectoring that has also surrounded the issue – slightly ashamed of eating. As a result, people could be more likely now than ever to underplay the quantities they do eat, an effect which might be more pronounced when it comes to public displays of eating – that is, when we eat out.

Chilled prepared foods

The chilled food sector is here taken to encompass ready meals, ready-sliced products, sandwiches, prepared salads and so forth. As mentioned, the figures in Table 7 and Figure 6 include these foods in the general food categories – meat-based ready meals are included in the processed meat category, fish-based meals in the processed fish category and so forth.

The popularity of chilled prepared processed foods has grown enormously. These scarcely existed when the Defra food survey began in 1974 but have been growing rapidly in market share in recent years. According to the Chilled Foods Association,[138] the chilled foods sector is worth £7,357 million (2005 data) and has grown by 62% in the six years between 1999 and 2005.

This rise in popularity of processed chilled meals means that foods that would previously not have needed refrigeration (at least at the retail and domestic stage) now need it. Take the potato as an example: our consumption by volume of potatoes may have declined since 1970 but the proportion of those that we do eat that are processed has risen. Such processed potato products tend to be heavily dependent, one way or another, upon the cold chain.[139] Traditionally the frozen chip has

[135] Becker, W. and Welten, D. (2001). Under-reporting in dietary surveys – implications for development of food-based dietary guidelines *Public Health Nutrition*: 4(2B), 683-687
[136] Pikholz, Swinburn, B., Metcalf, P. (2004). Under-reporting of energy intake in the 1997 National Nutrition Survey *The New Zealand Medical Journal*, Sep 24;117 (1202)
[137] Pikholz, Swinburn, B., Metcalf, P. (2004). Under-reporting of energy intake in the 1997 National Nutrition Survey. *The New Zealand Medical Journal*, Sep 24;117 (1202)
[138] See Chilled Food Association www.chilledfood.org/Content/Market_Data.asp; their estimates are based on published sources and industry data
[139] Fresh potatoes also need to be stored at a constant temperature of around 6°C but only in the relatively efficient cold store, not in the shop. Retailers are also refrigerating cardboard, film and plastic

dominated but sales here are now static;[140] instead we are seeing a growth in chilled potato dishes. A casual look through the offerings on display at even a small supermarket store will reveal a great number of potato dishes – garlic mashed potatoes, Bombay potatoes, potatoes Dauphinoise, even ready-baked potatoes.

The growth in chilled food not only has implications for retail and domestic refrigerator use, but also for transport and transport emissions. While freezers may be more energy intensive to run than refrigerators, when it comes to mobile refrigeration, the transport of chilled foods is more energy intensive than the transport of frozen food.[141] It is also the case that the manufacture, distribution and replenishment cycle of chilled foods are more rapid than that of frozen foods because of their shorter shelf lives. Many of them (although not all) also tend to be less dense – compare pouches of single-serve fresh peas with their frozen equivalents – which means that they take up more space both in the vehicle and on the shelf. Perhaps more importantly still, there are fewer opportunities for consolidating loads in the chilled food sector, as different foods need to be kept at different temperatures. This means that vehicle fill rates can be sub-optimal, leading to more vehicles for a given volume of goods. Hence the combination of more rapid turnovers with greater space requirements could lead to more vehicle deliveries in more energy-demanding refrigeration units. Whether the greater energy requirements for transport and the greater shelf space needed for display counterbalance the greater energy required to store food in a frozen, as opposed to a chilled state, is not known. It cannot however be taken for granted that the trend towards greater consumption of chilled foods at the expense of frozen, is in energy terms, an improvement.

Indeed the common perception that chilled foods are growing *at the expense of* frozen foods is not entirely accurate. While retail sales (and volumes) of frozen food are static,[142] in the catering sector, it appears that volumes of frozen food are growing at about 5% per annum.[143] One might also wonder whether the rapid growth in demand for chilled food has occurred not so much at the expense of frozen food, as of ambient or less-processed chilled food. Examples include ready-sliced chilled pineapples, ready-to-bake garlic bread and so forth.

Unprocessed perishables

Leaving both chilled and frozen processed foods aside, the form in which fresh *unprocessed* foods are presented to us for sale also has implicatons for refrigeration dependence. Root vegetables and tubers are a case in point here. These are presented to us, with the mud washed off them, at ambient temperature. However, while these tend not to be displayed refrigerated on supermarket shelves, they certainly are refrigerated at earlier stages in the supply chain and it is possible that the need to do so has been exacerbated or intensified by the preliminary washing that is now the norm for all such produce.

'Dirty' soil-on produce is now the preserve of the small box delivery scheme. It has been argued by some, however, that roots and tubers in their dirty, soil-on state, store better and have less need for refrigeration than those that have been washed.[144] One large organic grower stores potatoes unrefrigerated from October through to May with

[140] *Fresh Fruit and Vegetables* – UK, May 2005, Mintel
[141] Robert Heap, Cambridge Refrigeration Technology, various personal communications, 2006
[142] Retail frozen food volumes stabilise, British Frozen Food Federation, September 2006. See http://www.bfff.co.uk/RetailFrozenStatsAug06.pdf
[143] *Market Dynamics for Frozen Foods*, British Frozen Food Federation, April 2005. See http://www.bfff.co.uk/Market%20Dynamics%20for%20Frozen%20April%2005.doc
[144] Peter Melchett, Soil Association and Peter Segger, Organic Farm Foods Ltd, personal communication October-November 2006

little loss of quality.[145] Washed roots and tubers are, it has been suggested, more vulnerable to diseases since they are more likely to receive nicks in the skin surfaces where bacteria and fungi can lodge.[146]

In short, customer expectations even of unprocessed foods (or the expectations that are engendered in us by the retailers – this is not the place for that discussion) have knock-on effects on energy use at other points in the supply chain. This is perhaps an area that might be worth looking at more closely, particularly since there are no signs within the Defra research portfolio that this is an approach to be questioned.

Another area that may merit further exploration is the difference in the keeping properties of organic versus non-organic produce. Unfortunately a straightforward like-for-like comparison is not always possible because there will often be differences in the types of varieties grown. Many organic growers, for example, will grow for flavour rather than appearance or keeping properties. For the larger, conventional, supermarket-driven growers however, the reverse may be the case. This, incidentally, is interesting in view of the fact that many in the environmental movement criticise the commercial motivations of the larger players' quest for good storage properties – there may in fact be an environmental upside to it.

It may also be that since in the UK the overall supply of organic produce is small and demand great, organic growers manage to sell their produce soon after harvest, hence the storage potential of their produce is not put to the test.[147] This may particularly be the case with tree fruit such as apples, which are traditionally stored for several months.

For green vegetables and salad crops, whether conventionally or organically grown, the cold chain is critical, hence, from a refrigeration-dependency point of view, there is no difference between the two farming systems.

One issue that is worth mentioning in the organic versus conventional debate is the issue of post-harvest fungicide applications. Apples serve as an illustration. UK-grown apples, unlike those grown in other parts of the world, are particularly prone to rots[148] which infect apples in the orchard during apple development, remain symptomless and subsequently develop in store.[149] Apples grown in other regions, however, are more prone to post-harvest rots such as Botrytis and Penicillium; these are wound pathogens that invade fruit through damage at harvest. Such rots also occur in UK apples but are relatively less important. While the application of fungicides post harvest is one way of controlling rots, this tends not to be practised by UK growers because of public (and by extension supermarket) concerns about pesticide residues. Alternative approaches, including fungicide treatments around blossom time and pre-harvest are pursued instead.

The desire to cut pesticide use (driven, perhaps, by shopper concerns) has led to the reappraisal of non-chemical techniques such as 'ethylene scrubbing'. Air in the store is sucked through a precious-metal catalyst that runs at 250°C. The air is then returned to store sterile and ethylene free, using no chemicals. This is a highly

[145] Peter Segger, Organic Farm Foods Ltd, personal communication, October 2006
[146] East Malling Research Centre, personal communication, October 2006
[147] This is based on a conversation with East Malling Research Centre; however, to verify this, it will be necessary to talk to organic farmers themselves, especially those growing produce such as apples, which can be stored for some time
[148] Such as brown rot, Nectria rot, Phytophthora rot, Gloeosporium (Angela Berrie, East Malling Research Centre, personal communication, October 2006)
[149] Angela Berrie, East Malling Research Centre, personal communication, October 2006

energy-intensive process and so far the energy costs have precluded its use. However, it is possible that with the drive to reduce chemical use the scrubber technique may be reappraised in a more favourable light.

On the whole and whatever additional aids used (including SmartFresh and ethylene scrubbing), for organically and conventionally grown produce alike, refrigeration is an important tool and indeed the main tool used for delaying rotting and preserving fruit quality. Cold storage also enables UK growers to compete with imported fruit – Cox and Gala apples are usually stored up until March time while some other dessert varieties can be stored for longer still. Bramleys can be stored until August of the following year. The relative merits of storing indigenous produce versus importing in-season produce from overseas are discussed in detail in another FCRN publication;[150] but to summarise, relative merits of one over the other are finely balanced and depend upon the time of year, length of storage and various other factors.

Notions of quality

Another factor that may have affected the need for refrigeration is the expectation not just that all foods should be available all year round, but that they should always be of a specific and consistent quality.

Our definition of 'acceptable quality' has changed over time. For instance, apples which have been stored for a few months unrefrigerated develop a softer, chewier texture. Some people rather like this[151] but the industry today is adamant that today's customer will not accept fruits in this state.[152] Hence the need for highly controlled refrigerated storage to meet quality expectations.

Using apples as an example again, it may also be that our definition of which particular varieties are considered acceptable has narrowed. The UK climate supports the cultivation of a wide variety of apples which reach maturity over a broad period of time. Some, for example, can be harvested as early as August and others as late as the end of October;[153] this in theory means that with such a long growing season there is less need for long-term storage. However, in a situation where only a few varieties are considered to be acceptable (the industry notes that we demand very sweet, very crisp apples) the range of possibility is narrowed considerably. The few apple varieties that we do approve will either have to be stored beyond their growing season or substituted with imported varieties that possess the requisite properties.

To modify this point slightly, it is has already been highlighted that supermarkets often specify produce that stores well (although they are also very willing to stock fragile berries and other fragile produce if the profit margins are high) and have been the subject of criticism for so doing. Many of today's commercially popular apple varieties such as Gala, Braeburn, Granny Smith and Cox also keep well; a fragile type such as James Grieve, on the other hand, will keep for no more than a few weeks. It is possible that were supermarkets to mainstream the less robust varieties, in order to maintain a rolling supply of new-crop indigenous fruit, one consequence would be more waste. This of course raises many questions as to the merits of the centralised supply chains favoured by supermarkets. While generally efficient from a transport perspective, these may in themselves create other environmental problems with consequences for greenhouse gas emissions.

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[150] Garnett, T. (2006). *Fruit and vegetables & UK greenhouse gas emissions: Exploring the relationship*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey, September 2006

[151] Personal communications

[152] WorldWide Fruit, ongoing personal communications

[153] Brogdale Horticultural Trust, see http://www.brogdale.org/nfc_home.php

Possible new developments

Finally, for this subsection, it is very possible that in future years new products will be launched on the market which are highly refrigeration dependent. Thinking back ten years, for example, one might not have anticipated the development of chilled bread such as naan or garlic bread. Another example is the ready-cut carrot; while ordinary loose carrots are sold unrefrigerated, their batonned brethren are displayed in fridge cabinets (both of course will be stored chilled up until the retail stage). Coming years may see such trends escalating. The outcome may well be a growth in the installation of refrigerated display cabinets in store and other associated refrigeration infrastructure, together with a growth in the size of domestic fridges.

Variety and choice

Many supermarkets stock well over 40,000 product lines and even a small Tesco Express convenience store will stock well over 2,000.[154] We now have access to almost anything we want, wherever we are, at whatever time of day we want it.

So far it has been argued that changes in the *kinds* of foods we like to eat and which are provided by food manufacturers and retailers have had implications for refrigeration energy use. But – and this is a separate issue – has the massive growth in the sheer *variety* of foods we can choose from also had energy implications?

This is a difficult question and raises at least two sub-questions. First, does more variety and choice lead to greater overall *consumption*? And secondly, does the *production* of a greater variety of food lead to greater energy use by manufacturers and distributors?

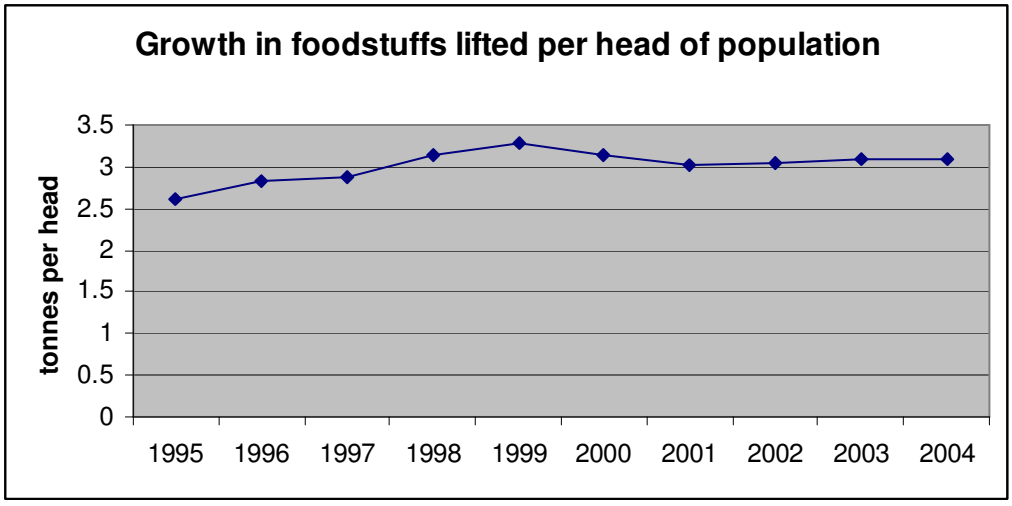
This is not an area that appears to have been much examined in the specific context of the food chain's environmental impact. However, there is a body of literature, reported in the *Journal of Consumer Research* by Kahn and Wansink,[155] which looks at the link between food variety and consumption. It is now fairly well accepted that greater variety, unless one is physically stuffed, does indeed encourage people to eat more. However, Kahn and Wansink[156] conducted a study (with Jelly Babies sweets) which showed that not only does increasing the actual variety of an assortment increase the quantity that people consume but people are stimulated to consume more even when the perceived variety is illusory (i.e. the same Jelly Babies arranged and presented in different ways). The authors highlight the relevance of these findings for nutrition policy – the more variety we are presented with, the more we eat – but might there also be environmental implications?

While this and the other studies Kahn reviews show that in a single meal, or on a single eating occasion, more choice (or the perception of more choice) encourages people to eat more, how applicable are these findings at a larger scale? As already highlighted, our purchases of food by weight of food has stayed more or less constant over the last thirty years. Even allowing for under-reporting (and an increase in the extent to which we under-report), greater choice does not appear to have led to drastic increases in the amount we buy, although as noted earlier since our calorific needs have declined we may be throwing away more food than we did before, and this will have environmental consequences. Food in this respect is different from most other areas of consumption – we can always have two televisions instead of one, or

[154] See http://www.tesco.com/talkingtesco/productChoice/
[155] Kahn, B. E. and Wansink, B. (2004). The Influence of Assortment Structure on Perceived Variety and Consumption Quantities. *Journal of Consumer Research*, Volume 30
[156] Kahn, B. E. and Wansink, B. (2004). The Influence of Assortment Structure on Perceived Variety and Consumption Quantities. *Journal of Consumer Research*, Volume 30

16 pairs of shoes instead of two – but there is only so much we can actually eat over a sustained period of time. However, Figure 7, plotting Department for Transport data on the tonnage of goods lifted against population figures shows that, in recent years at least, the quantity of foods transported has indeed increased.

Figure 7: Growth in foodstuffs lifted per head of population



Source: Road Freight Statistics 2005, Department for Transport and Office of National Statistics

Since the absolute volume of food has not changed much, is there something else about the manufacture of variety – the second sub-question – that is environmentally problematic? Does it matter from an environmental perspective if we can choose between two virtually identical types of breakfast, given a constant level of demand for breakfast cereal? (From a marketing perspective of course the greater range on offer might stimulate an increase in cereal sales but this may be at the expense of bread, say, or eggs or some other breakfast type food.)

Again, there does not seem to be a great deal of research in this area. Tang and Yam, of Hong Kong Polytechnic Department of Industrial and Systems Engineering, point out (in the context of electrical goods) that manufacturer strategies of offering a wide range of products creates waste during the manufacturing stage.[157]

In the absence of proper research, a few thoughts are offered here as a starting point for further exploration.

As regards a single processing plant: where this is production of variants on an existing theme (such as different flavours of yoghurt) there will be a need to stop and wash out the equipment between different batches, and this will require energy.[158]

Where the same or similar products are offered in a range of different sizes or packaging types, there may be an increase in demand for packaging and its associated raw materials. This has been countered to some extent by the light-weighting of packaging materials but there has nevertheless still been a growth in

[157] Tang, E. P. Y. and Yam, R. C. M. (1996). Product variety strategy – an environmental perspective, *Integrated Manufacturing Systems 7/6* 24–29

[158] Berlin, J., Sonesson, U. and Tillman, A. M. (2007). A life cycle based method to minimise environmental impact of dairy production through product sequencing, *Journal of Cleaner Production*, volume 15 issue 4, pp. 347-356

packaging over time (3.5% between 1999 and 2004)[159] and so this still qualifies as an environmental impact (although the relationship between packaging and waste is a difficult one and it has been argued packaging helps to reduce food waste[160]).

Where the nature of the food offer is 'fixed', this could have an environmental impact. To take the yoghurt example again: today, if a yoghurt producer offers a range of five different flavours of yoghurt, those five different flavours always have to be manufactured and the taste of each separate type (strawberry, say) needs to be the same whatever the time of year. In the case of strawberry yoghurt, this means that strawberry supplies will need to be sourced and then frozen to ensure that that particular product can be produced all year round. It also means that supplies of another fruit ingredient (damsons) will not be used even when they are readily available and at lower environmental cost.

Yoghurt is a relatively simple product. Many of the foods on offer can contain twenty different ingredients all of which have to be consistent in their manufacturing and sensory properties, and which may not be substitutable.

Another point to note is that while the basic ingredients of our diet have not changed much (fruit, vegetables, meat, grains, dairy and so forth), the way in which they are processed certainly has, and requires particular, specialised equipment. So while our consumption by volume of potatoes may have stayed the same, the different technologies needed to freeze, shape, extrude and otherwise process the potatoes that we do eat will entail energy both in their manufacture and their use. And the greater the variety of products on offer, the greater the quantity and variety of supporting infrastructure and technology that is needed.

One development that has paralleled the increase in the variety on offer is shift towards large-scale, centralised manufacturing. It has been argued[161] that economies of scale can bring ecologies of scale: large, efficient centralised production systems combined with bulk shipments of goods often use less energy per volume of food than smaller, more localised counterparts. Likewise a loaf of bread baked in a large industrial oven can represent lower energy use than one baked in a local bakery.[162]

This may well be the case. The point to make here however is that we do not just have access to one, standard, industrially produced type of orange juice, or bread, or whatever it might be, but to many. Sometimes the different brands on offer can disguise the fact that the products are produced in the same place and then branded differently. But each of the different brands will require slightly different packaging formats, slightly different distribution networks (and there may also be variations in the basic recipe), which again could lead to greater energy use.

There is also transport to consider. If everyone is to have access to a wide variety of the same things then transport systems are necessarily complex. To illustrate in highly simplified terms: instead of six manufacturers, say, supplying to the South East region and a different six suppliers supplying to the North West, the six South East suppliers now supply to the North West and vice versa. This means both regions have twelve suppliers. When one also adds the fact that these twelve suppliers will rely on their

[159] *Packaging in the supply chain*, Incpen research facts, Incpen 2006
[160] *Packaging in the supply chain*, Incpen research facts, Incpen 2006
[161] Schlich, E. H. and Fleissner, U. (2004). The Ecology of Scale: Assessment of Regional Energy Turnover and Comparison with Global Food, *Int J LCA*
[162] Andersson K and Ohlsson T. (1999) Life Cycle Assessment of Bread Produced on Different Scales, *Int. J. LCA 4* (1) 25-40

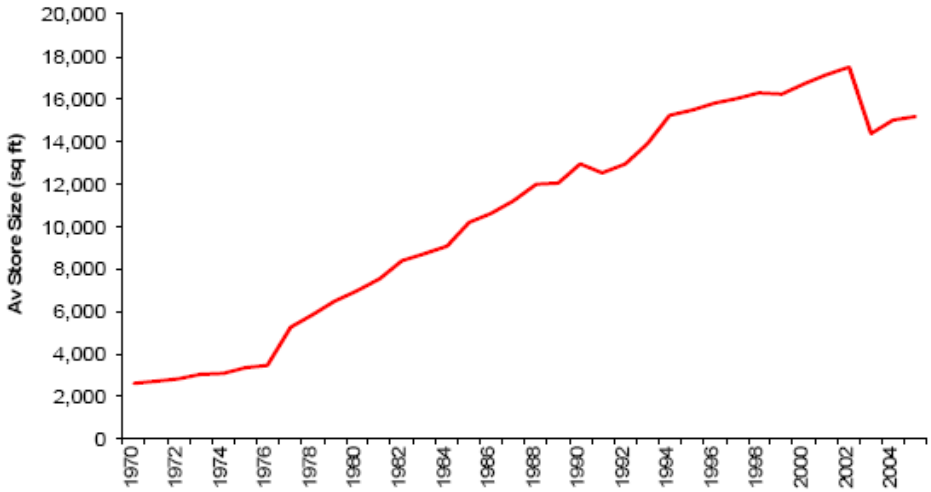
own complex chain of suppliers who supply them, the consequence is more transport and more need (for some foods) for refrigeration and intermediary storage facilities.

It has been pointed on many occasions[163,164,165] that the combination of bulk supplies and large, relatively efficient vehicles can make nationalised distribution systems less CO_2 intensive than the transport of smaller quantities of goods, in less-efficient vehicles, at a more local scale. But when there are lots of nationalised distribution systems supplying all goods at all times to all areas, the impacts may not be quite so clear. And as highlighted before, non-availability has become unacceptable.

Finally, as the range of foods on offer grows, so does the shelf space (including refrigerated shelf space) required to fit it. This can mean more energy used to build, heat, light and refrigerate stores. Figure 8 shows the growth in the average size of the major multiples' grocery stores over twenty-five years.

Of course, some of that growth has arisen because of the increase in the quantity and range of non-food products that the multiples offer. It is also the case that much of that growth will have occurred at the expense of independent local stores. The same volume of goods and the same area of shelf space may always have been there but contained, less visibly, in lots of little shops. It would be useful to know whether the increased quantity and range of foods offered in supermarkets has led to an absolute increase in the volume of foods on offer.

Figure 8: Average size of major multiples' grocery stores (1970-2005)



Source: *Grocery retailing 2005*, Institute of Grocery Distribution

In short, the relationship between variety and environmental impact is not clear but it needs to be clarified. Since the goals of more choice, total consistency and ubiquitous supply and availability are at the heart of the food industry's business model and since at the same time they are being asked to reduce their greenhouse gas emissions in

[163] Garnett, T. (2004). *Wise Moves: exploring the relationship between food, transport and CO_2*, Transport 2000
[164] Schlich, E. H. and Fleissner, U. (2004). The Ecology of Scale: Assessment of Regional Energy Turnover and Comparison with Global Food, *Int J LCA*
[165] Andersson, K. and Ohlsson, T. (1999). Life Cycle Assessment of Bread Produced on Different Scales, *Int. J. LCA 4* (1) 25-40

line with national-level reductions[166] then the fundamental sustainability of its business model certainly needs to be assessed.

Health and safety

Legislation

Since the first law affecting food safety was passed in 1860, a great deal of legislation has been introduced with the purpose of safeguarding the quality of our food.[167] Early legislation sought specifically to address chemical adulteration rather than bacteriological contamination, since the role of bacteria was not fully understood. Anne Hardy, Professor in the History of Modern Medicine, notes that it was when records of outbreaks started to be collected in the 1880s that the term food poisoning, actually came into use and its links with bacteriological infection acknowledged.[168]

The first piece of UK legislation with specific relevance to temperature control, the Food Hygiene Regulations, was not passed until as late as 1970; this specified that certain foods had to be cooled to below 10°C without delay.

In several amendments to the legislation, the maximum temperature of certain foods was brought down to 5°C. However the introduction of the Food Safety (Temperature Control) Regulations in 1995 then raised the legal maximum[169] to 8°C, which is internationally the highest legislated temperature for chilled foods.[170] This amendment is opposed by the Chilled Food Association (CFA), which argues that the Statutory Code should recommend 5°C as a target operating temperature,[171] with 8°C as a legal maximum. Higher legal temperatures would, in the CFA's view, have the effect of reducing the shelf life of many perishable foods, as well as increasing the risk of food safety hazards. Since 1 January 2006 food hygiene legislation has changed again, to fall in line with EU legislation,[172] but the new legislation does not affect stipulated temperature-control requirements.

At the international level, the ATP or *Agreement on the International Carriage of Perishable Foodstuffs* lays down temperature requirements and vehicle specifications (such as insulation standards) for the transboundary transport of perishable foods excluding fruit and vegetables. It was drawn up by UNECE (the United Nations Economic Commission for Europe) in 1979 and has been amended many times since then. In the UK, the Treaty only applies to international journeys; whereas in France, for example, it is used as a national standard too.

As regards frozen foods, 1992 saw the introduction of the EU Quick Frozen Foodstuffs regulation which required that foods labelled as Quick Frozen[173] foods be stored at -18°C or lower. Other than this there is no other legislation that specifically dictates temperatures of frozen foods.[174]

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[166] *Food Industry Sustainability Strategy*, Defra, 2006. See http://www.defra.gov.uk/farm/sustain/fiss/fiss2006.pdf

[167] For a chronology of food safety legislation from 1959 onwards see the web pages of Professor David Jukes at Reading University, http://www.foodlaw.rdg.ac.uk/uk/reg-date.htm#2006

[168] Hardy, A. (1999). Food, Hygiene, and the Laboratory. A Short History of Food Poisoning in Britain, circa 1850-1950, *Social History of Medicine*, Vol. 12 No. 2, pp. 293-311

[169] For foods likely to support the growth of pathogenic micro-organisms or the formation of toxins

[170] Kaarin Goodburn, Chilled Food Association, personal communication, October 2006

[171] Kaarin Goodburn, Chilled Food Association, personal communication, October 2006

[172] For more information on EU legislation as it affects specific foodstuffs, see 'Workroom temperatures in places where food is handled', HSE Food Information Sheet No 3 (revised), Health and Safety Executive http://www.hse.gov.uk/pubns/fis03.pdf

[173] A process that preserves the texture of frozen foods

[174] John Hutchings, Cold Storage and Distribution Federation, personal communication, November 2006

Such legislation is likely to have increased the quantity of cold infrastructure manufactured and used, and perhaps reduced the temperature at which chilled and frozen foods are kept. This in turn could have increased energy use. The relationship between refrigeration and food safety is explored further in Section 6 below.

Public concerns

It is probable that our definition of foods requiring refrigeration has broadened. While to our knowledge this issue has not been formally researched, a glance through the average household fridge today often reveals bottles and jars of preserves – jams, chutneys, ketchups and pickles – which by definition do not need to be refrigerated. In addition, many fruits and vegetables, as well as eggs are now kept in the fridge where previously they were not, either because it was not considered necessary, or because there was no refrigerator.

It is possible that in future years our tolerance of practices thought to be 'risky' may decline further. Some have argued that we now live in a highly risk-averse culture.[175] However our perception of risk is not necessarily the same as our treatment of potentially risky practices. In the case of food, while our concerns about hygiene and safety may be on the increase, it is also the case that by buying ready-packaged foods the responsibility for safety is offloaded on manufacturers and distributors further up the supply chain. One might speculate that we end up engaging in more risky (or unhygienic) practices because we don't feel responsible for our own safety. One study found that for young professional men this is indeed the case.[176]

Future years could see this risk-aversive behaviour growing and this in turn could stimulate the greater use of refrigeration. One might also speculate that as we demand fewer preservatives in our food (both artificial and, like salt and sugar, natural), the temperature-sensitivity of some of our foodstuffs may increase. There does not, however, appear to be any research that investigates trends in additives either natural or otherwise, so firm conclusions cannot be drawn here.

A changing climate

There is also our warming climate to consider. A report by the Met Office identified increased summer air-conditioning and refrigeration demand as the key factors affecting the balance of energy supply and demand in future years.

This will affect all stages in the cold chain. Foods that at present tend not to be stored in a refrigerator (eggs, for example are currently retailed on open shelves) may need to be refrigerated in coming years. Moreover, in hot weather our consumption of chilled and frozen foods such as ice-cream, yoghurts, salads, chilled drinks and so forth is also likely to grow.

[175] Giddens, A. (1999). Risk and Responsibility, *The Modern Law Review*, vol 62, No.1, pp. 1-10

[176] Redmond, E. C. and Griffith, C. J. (2004. Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal,* Vol. 106 No. 8, pp. 581–597

SECTION 5: TEMPERATURE CONTROL AND WASTE: WHAT IS THE RELATIONSHIP?

Of course the great thing about refrigeration is that it stops food from going bad. Since wasted food represents a waste of all the embedded energy used to grow, process and transport it, the added energy requirements of refrigeration need to be balanced against the 'wasted' CO_2 that would result if the food were to spoil. This is an issue that already discussed in another FCRN publication[177] but a few additional points are made here to suggest that the equation 'more refrigeration equals less waste' may not be totally straightforward.

As a starting point, there is probably a relationship between appropriate refrigeration and less waste given two *identical* sets of purchases and an *identical* period of time before it is eaten. Refrigerated food lasts longer and as such is less likely to go rotten and need to be thrown away. Temperature control along the whole of the supply chain also enables producers (whether farmers or hobby gardeners) to manage seasonal gluts which cannot all be eaten in one go. Foods can be frozen and consumption can then be spread over a period of weeks or even months.

Indeed one Brazilian study[178] compared two food stores; one without a refrigerated unit (store A) and one with (store B). The authors found waste in the un-refrigerated Store A to be as high as 28%, while for refrigerated Store B waste levels were about a third of this, at 10%.

However it does not necessarily follow that in the less refrigerator-dependent past, households wasted more food, nor that in a (hypothetical) less refrigerator-dependent future, waste levels will inevitably increase. As discussed above, the *way* in which food is shopped for and managed affects the need for temperature control and the degree of wastage.

This section explores some of the other societal and economic factors that are likely to have a bearing on what and how much we waste.

a. The cost of food

The socio-economic context within which we consume food has changed markedly. The amount we spend on food, relative to spending on other household goods and services has been steadily declining. Between 1982 and 2004/5 the percentage of household expenditure that went on food and non-alcoholic drinks fell from 21% to 16%.[179] And when food is relatively cheap, wasting it is, financially speaking, relatively unimportant.

It would follow that richer people waste more food than poorer people, since they can afford to. There has unfortunately been little recent research which looks at this subject. However one recent study by the Food and Agriculture Organization (FAO)[180] reviews some of the older research of the 1970s and 1980s and finds that many

[177] Garnett, T. (2006) *Fruit and vegetables & UK greenhouse gas emissions: Exploring the relationship*. Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey, September 2006
[178] Fehr, M., Calçado, M. D. R., Romão, D. C. (2002) The basis of a policy for minimizing and recycling food waste, Environmental Science & Policy 5 (2002) 247-253
[179] Table 4.2: Household expenditure as a percentage of total expenditure 1982 to 2004-05 in *Family Spending: 2005 edition*, Office of National Statistics
[180] Sibrián, R., Komorowska, J., Mernies, J. (2006). *Estimating household and institutional food wastage and losses: Measuring food deprivation and food excess in the total population*, Food and Agriculture Organization

studies do indeed show such a link, albeit complex, between higher waste levels and higher incomes, both in absolute terms and relative to the quantities purchased. Some studies find that high-income households with adequate storage facilities also produce greater quantities of *edible* food wastage. Low-income groups may however waste more of certain foods, because such foods feature more strongly in their diets. In many hot developing-world countries, access to a fridge is critical in reducing food waste, despite any differences in attitudes to wasting food *per se*. It might also be that poor people are more likely to buy substandard products which are perhaps already nearing the end of their edible lives, so there is less of a time margin for eating available. A few studies do not find differences according to income levels, even once household size and geographical regions are taken into account. The variation in conclusions reflects differences not just in geographical location and household characteristics but also in the way food waste is defined and measured and in methodological differences. On the whole, however, it seems fair to say that if one can afford to waste food, then one does.

b. Food and its symbolic import

Do we waste less now than we did in the past and, if so, to what extent has refrigeration curbed waste levels? Unfortunately this question is impossible to answer partly because the data are not available and partly because the context within which we consume has changed so radically that like-for-like comparisons are not possible.

We have always wasted food, partly for unavoidable practical reasons, but partly because conspicuous consumption and conspicuous waste have always proved very effective ways of displaying one's wealth and status. However, leaving the very rich aside it might be worth exploring how our attitudes to food waste within the mainstream population may have changed and why, other than the economic reasons highlighted above, this might be.

Food plays a central part in the imagery and rituals of all the major world religions.[181] Now in our culture of material plenty where religion is relatively unimportant to all but a vocal minority, one might tentatively suggest that food has been divested of its moral or religious import. It is simply another commodity and as such can be wasted without opprobrium.

We are certainly guilty about food but this guilt now centres on bodily aesthetics and we are happy to waste food if it makes us thinner. Tellingly, while in the past children were urged to eat everything on their plates because 'wasting food is a sin', now magazines urge their body-obsessed readers to '*Master the "skill" of leaving uneaten food on your plate*.'[182] It is striking that we appear to be more concerned about excessive food packaging as a society than about wasted food.

c. The safety net effect

The relationship between changing technology and changing consumer behaviour, may also have implications for food waste. Today's ability to store food, in a sense

[181] One thinks of the bread and wine in the Christian Communion, the Kashrut dietary laws of Judaism, the concept of Halal and Haram in Islam and the vegetarianism embedded in the Hindu food traditions, as well as the various rituals of fasting and feasting common to them all

[182] See for example some websites with links to US Government health bodies:
http://www.shapeup.org/atmstd/sud10v3/sud10s6.php
http://health.howstuffworks.com/usda-diet-strategies-for-dining-out-ga1.htm;
http://www.diet-blog.com/archives/2006/10/10/10_questions_to_ask_before_changing_your_diet.php
http://www.fns.usda.gov/TN/Resources/POC_topic9.pdf

acts as a kind of safety net – the food can always keep longer, goes the thinking – except that suddenly one finds it has gone off. In the days when there was no safety net it was necessary to think ahead and plan more systematically. Food needing eating got eaten. One might speculate too that as cooking skills decline there is less of a tendency to, say, make scones out of sour milk or soup out of wilting vegetables.

The extension of store opening hours may also have had a 'safety net' effect with possible consequences for food waste (the greater energy requirements of longer opening hours has already been noted in Section 5 above). For example, if one finds one has run out of eggs but the shops are shut, then dinner will simply have to be eggless. Something will be produced out of what is available in the kitchen. However, today, where some retail outlet is open whatever the hour, a quick trip to the shops will solve the egg shortage and the omelette can be made. Food, then is not prepared out of what there is but out of almost anything one could conceivably want – this links to the earlier point made about availability and variety. Other foods that are available in the home but which do not appeal can be left uneaten even if they are nearing the end of their storage life. In other words, it may be that a sense of eating things because they 'need eating' is disappearing. One might speculate – but it is speculation only – that variety and round-the-clock availability – has contributed to a shift in our attitudes to, and behaviours affecting, food waste.

In conclusion then, while refrigeration has the technical capacity to reduce food waste, the changing attitudes and behaviours which have gone hand in hand with the uptake of refrigeration may have had a counterbalancing effect.

SECTION 6: REFRIGERATION AND FOOD SAFETY

One issue that clearly needs addressing in the context of refrigeration dependency is food safety. No one wants to become ill or die of food poisoning. But is a food system which uses less refrigeration inherently more risky?

As with waste, while the short answer is yes, the long answer may be more nuanced.

For a start, one needs to examine the significance of temperature control relative to other biological aspects of food safety in order to ascertain how important the former might be. A historical approach is also needed since, as shown above, widespread use of refrigeration is a fairly new phenomenon. Digging around a little in the past to see what sort of food poisoning we suffered from then and how far temperature control played a part, might reveal some useful insights. It may, for example, help us identify where in the supply chain refrigeration is essential and how far changing the way we handle, supply, shop and cook for food could substitute for refrigeration, without increasing consumer risk. Unfortunately, there does not appear to be a great deal of research into this area. Moreover it is perhaps overly simplistic to view food poisoning and hygienic (and unhygienic) practices in isolation from the social, demographic, economic and spatial context in which they occur. The way we shop, how we design our houses and the sorts of foods we expect to eat (as discussed above) will have just as much of a bearing on the riskiness of the food supply chain as do direct behaviours affecting food safety.

Nevertheless, since food poisoning and temperature control are so closely associated in health and safety practices and legislation, it is important, in our view at least to raise some questions:

a. **Trends**: How has the incidence of food poisoning and the main causes of food poisoning changed over time? How has the importance of temperature control, relative to other aspects of food safety changed?
b. **Food poisoning today**: What is the contribution of poor temperature control to food poisoning incidents and where along the supply chain do these incidents of occur? How has this changed over time?
c. **Household behaviours and practices**: What contribution today does inadequate temperature control make to the incidence of household-related food poisoning relative to other household practices with a bearing on hygiene (including hand washing, cross-contamination and so forth)? How has the knowledge of what constitutes good hygiene, and its practice, changed over time and how has this affected the incidence of foodborne illnesses?
d. **Food types**: Which are the main foods implicated in food poisoning incidents?
e. **Globalisation**: How have globalised supply chains affected the nature and the geographical spread of food poisoning outbreaks?

These are addressed in turn in the paragraphs that follow.

a. Trends

How has the incidence of food poisoning and the main causes of food poisoning changed over time? How has the importance of temperature control, relative to other aspects of food safety changed?

There are no comprehensive national level records of the incidence of food poisoning (of all kinds) before 1949. Information on outbreaks in the preceding decades are limited to localised records and accounts. However, according to Anne Hardy, a

medical historian, despite the lack of contemporary data there are good grounds for believing that foodborne infections were widespread in England by the 1850s.[183]

The nature and causes of these infections were however very different from the kind of food safety problems that we face today. Hardy argues that food poisoning was a relatively new phenomenon, and that it was the result of social change. Urbanisation was a major contributing factor as it had huge implications for the way food was supplied and distributed. Two telling indicators she cites are the growing incidence of typhus and diarrhoea afflicting urban populations and its spread by faecal contamination of the water supplies.

She also points out that long-distance transport networks – railways (from the 1830s) and steamships (from the 1860s) – also facilitated the spread of infections. Urban lifestyles gave rise to urban eating arrangements: 'fast food', such as ready-made sandwiches and pies for lunch and take-home roast dinners or fish and chips for dinner substituted for home cooking. All this, of course, sounds very familiar.

For a more detailed look at the sorts of problems associated with temperature-sensitive food, it is helpful to consider the milk supply chain in the Victorian era. The safety of milk is of course affected not just by storage temperature but by a number of other practices concerning its production and distribution. Milk was in fact a major cause of illness during the Victorian period, much of which can be attributed to the filthy conditions in which it was produced and distributed, as described by geographer Peter Atkins.[184] The problem started with farmers, few of whom washed either the cows or milking equipment; milk was often contaminated with pus and dung and other undesirables. Further along the supply chain, milk sellers rarely covered their pails and, worse, tended to adulterate the milk with water (a dilution rate of about 25% was average) to increase their profits.[185] If the water was dirty, which was a distinct possibility, diarrhoea was just one of the illnesses that resulted.

Milk was also constantly at risk of going off, and here is where temperature control becomes important. With the advent of the railways, urban farms began to lose their competitive edge (this was probably a good thing as urban farms were particularly filthy) but of course now the milk took longer to reach the customer. Average rail journeys could be up to five hours and although a form of refrigeration for trains (the Lawrence refrigerator) was developed in 1872, it took decades to be adopted. In fact refrigerated wagons were rarely used in the railway or road transport of milk before the First World War although there were cooling rooms in some of the railway depots.[186] Hence by the time the customer got round to drinking the milk, up to 24 hours could have elapsed. Contemporary observers noted that sour milk was one of the causes of summer diarrhoea.[187] Attempts were made to preserve the milk with the aid of chemical additives such as boracic acid[188] and formaldehyde.[189] These inhibited

[183] Hardy, A. (1999). Food, Hygiene, and the Laboratory. A Short History of Food Poisoning in Britain, circa 1850-1950, *Social History of Medicine*, Vol. 12 No. 2, pp. 293-311
[184] Atkins, P. J. (1992). White Poison? The Social Consequences of Milk Consumption, 1850-1930, The Society for the Social History of Medicine
[185] Atkins, P. J. (2006). *Food quality and regulation in history: some theoretical considerations*, XIV International Economic History Congress, Helsinki, 2006, see http://www.helsinki.fi/iehc2006/papers1/Atkins.pdf
[186] Spencer, C. *British Food: An extraordinary thousand years of history*. Grub Street, London, 2002
[187] Spencer, C. *British Food: An extraordinary thousand years of history*. Grub Street, London, 2002
[188] Atkins, P. J. (1992). White Poison? The Social Consequences of Milk Consumption, 1850-1930, *Social History of Medicine*
[189] Atkins, P. J. (2006). *Food quality and regulation in history: some theoretical considerations*, XIV International Economic History Congress, Helsinki, 2006. See http://www.helsinki.fi/iehc2006/papers1/Atkins.pdf

the souring process but did not kill harmful bacteria, with the result that consumers wrongly thought that they were buying fresh milk. What is more, these chemicals, added in large doses sometimes at several points in the chain, were toxic in themselves. The alternative was to skim, condense and can milk. The resulting product, depleted as it was in vitamins A and D was, in nutritional terms, certainly not a desirable staple food. But this is what it became for the working classes and, worse, their infants.[190] Clearly more refrigeration in the milk supply would have helped reduce the incidence of milk contamination and provided an alternative to canned milk.

However, the most serious problem with the milk supply was not temperature related at all but concerned the prevalence of bovine tuberculosis in the dairy herd. Atkins[191] reports that during the period 1850-1950 at least half a million human deaths were directly attributable to bovine tuberculosis; those most affected tended to be young children who, predictably, were the main milk drinkers. The middle classes were, ironically, more susceptible, simply because they drank more of it than the poor.

In short, as Atkins[192] notes, '*Milk quality was so abysmal that the damage caused by disease may have outweighed the nutritional benefits*.' Diarrhoea, tuberculosis and rickets too (from vitamin D deficiency) were all consequences of the way milk was supplied and consumed. While lack of refrigeration was one element of the problem, other factors, mainly appalling standards of hygiene and disease in the dairy herds, were more damaging still.

The example of the Victorian milk supply chain is interesting in that it highlights how different food safety concerns affect populations at different stages in time because of the different social and demographic context in which they occur.

Another example can be drawn from food poisoning outbreaks during the Second World War. While no formal records were kept at that time, one contemporary medical observer estimated there to have been a sevenfold increase in the annual number of food poisoning outbreaks between 1938 and 1947. He was clear that this was a genuine increase rather than simply the result of more reporting.[193]

This is interesting particularly since, as often reported, the make-up of peoples' diets was on the whole healthier during this time of rationing than at any other period in history.[194,195] However, economic and social historians Michael French and Jim Phillips[196] note that infections spread more widely during this time because of another food-related war measure – the expansion of mass catering. Between 1941 and mid 1945 the number of meals served in catering outlets more than doubled from 79 million to 181.7 million. These outlets included military establishments, works canteens, and Government-run 'British Restaurants'. French points out that the

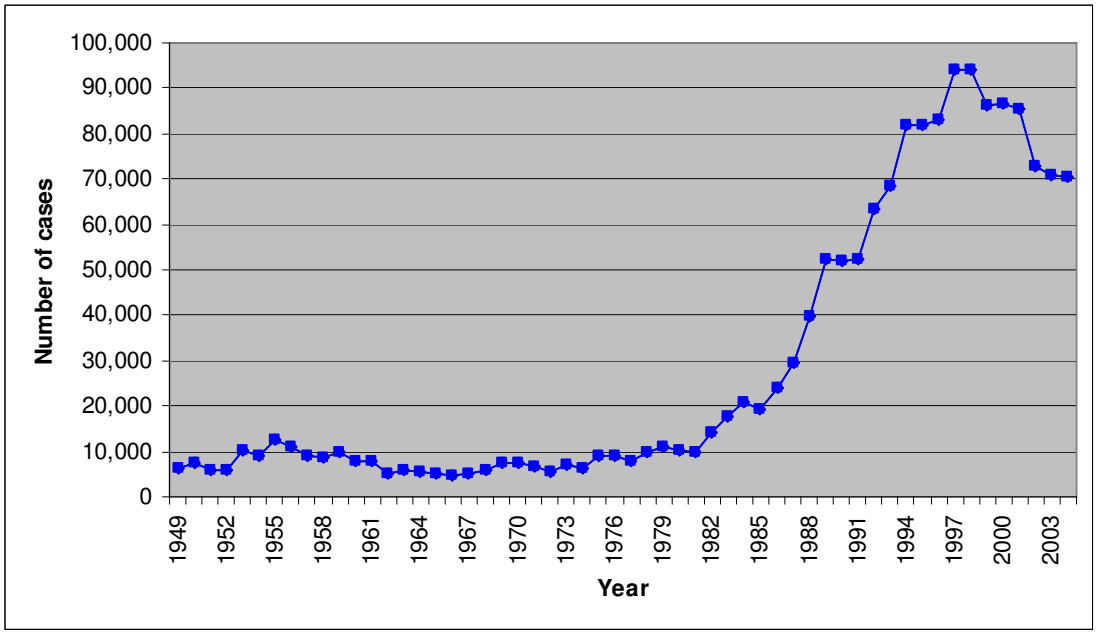
[190] Atkins, P. J. (1992). White Poison? The Social Consequences of Milk Consumption, 1850-1930, *Social History of Medicine*
[191] Atkins, P. J. Order and Disorder: The health implications of eating and drinking in the nineteenth and twentieth centuries. In Fenton, A. (ed) *Proceedings of the Fifth Symposium of the International Commission for Research into European Food History*, Aberdeen 1997, Tuckwell Press, Edinburgh
[192] Atkins, P. J. (1992). White Poison? The Social Consequences of Milk Consumption, 1850-1930, *Social History of Medicine*
[193] Dr Wilson, director of the Public Health Laboratory, referred to in: French, M. and Phillips, J. (2004), Windows and Barriers in Policy-making: Responses to Food Poisoning in Britain, 1945-1956, *Social History of Medicine*, 17(2), pp. 245-260. ISSN 0951-631X
[194] Lang, T., Barling, B. and Caraher, M. (2001). Food, Social Policy and the Environment: Towards a new model. *Social Policy and Administration*, 35 (5): 538-558
[195] Spencer, C. *British Food: An extraordinary thousand years of history.* Grub Street, London, 2002
[196] French, M. and Phillips, J. (2004), Windows and Barriers in Policy-making: Responses to Food Poisoning in Britain, 1945-1956, *Social History of Medicine*, 17(2), pp. 245-260. ISSN 0951-631X

greater use of reheated foods and the policy of centralising slaughtering in fewer large abattoirs increased the potential spread of any infection.

As for more recent years, Figure 9 below shows the number of food poisoning cases as a percentage of the population since 1949.[197] Interestingly, these fifty years also see a rise in domestic refrigerator ownership levels from near zero to near universal.

For England and Wales, the incidence of food poisoning per 1,000 people seems to have been steady until about 1980; the number of outbreaks then rises sharply for about fifteen years before falling slightly again and levelling off. Note that across all years the reported cases of food poisoning are certain to be far lower than the actual number of people affected.[198]

Figure 9: Notifications of food poisoning, 1949-2004



Sources: Statutory Notifications of Infectious Diseases (NOIDs) and historical data, Health Protection Agency; Office of National Statistics Population data, http://www.statistics.gov.uk/downloads/theme_compendia/Aa2006/AnnualAbstract2006complete.pdf

Note: the HPA data begin in 1949 whereas the ONS records give population figures only for 1931 and 1951, followed by 1961. Yearly estimates only start in 1969. The population figures for 1949 to 1969 therefore are simply averages.

This rise from 1982 was mainly caused by the outbreak of salmonella in poultry flocks. Once flocks started to be vaccinated (1994-5 for broilers and 1997-8 for layers) incidences of salmonella poisoning started to decline.[199] Note that salmonella cannot be killed by cold storage.[200]

[197] As opposed simply to absolute changes in numbers
[198] Redmond, E C. and Griffith, C. J. (2004). Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal* Vol. 106 No. 8, pp. 581–597
[199] Iain Gillespie, Health Protection Agency, personal communication, September 2006
[200] Nassib, T. A., Zin El-Din, M. and El-Sharoud. W. M. (2003). Viability of Salmonella enterica subsp. enterica during the preparation and cold storage of Egyptian soft cheeses and ice-cream. *International Journal of Dairy Technology,* Volume 56, p. 30

The rise in notifications also reflects the better identification and diagnosis of incidences of campylobacter poisoning. In former years these are likely to have gone unreported so a proportion of the apparent growth is deceptive. Some strains of campylobacter (but not all) will be killed by very cold temperatures (below 4°C).[201] However the main cause of campylobacter poisoning is through cross-contamination of chopping boards, dishcloths and cooking utensils.

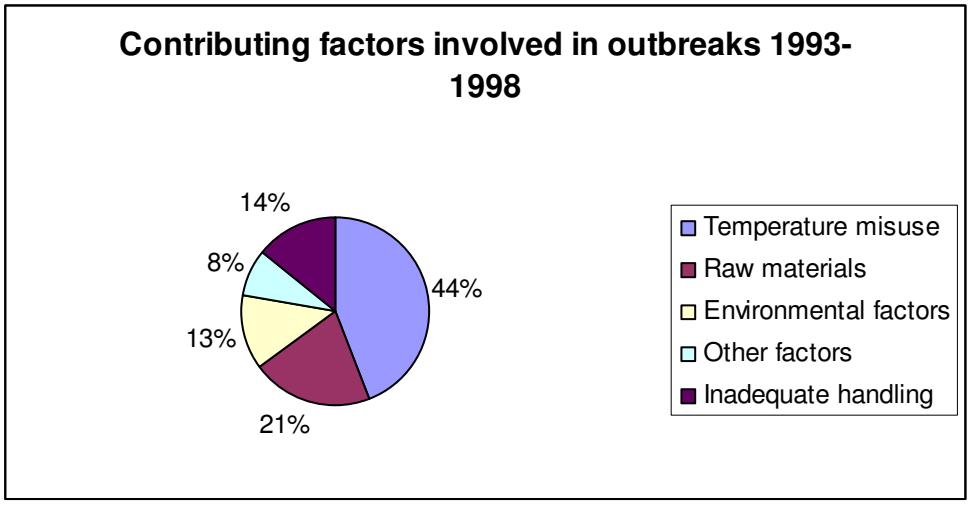
Many observers note that the epidemiology of foodborne disease continues to change. The food safety threats we face today will be different from those we face tomorrow. This is partly because of the way we produce and transport food. New pathogens arise and pose new threats. In addition, the demographics of our population continue to change.[202,203] Our population is aging and older people tend to be more vulnerable to foodborne illness. On the other hand, the very young are also at risk of foodborne illnesses – and there will be fewer of them around to be at risk in coming years.

b. Food poisoning today

What is the contribution of poor temperature control to food poisoning incidents and where along the supply chain do these incidents of occur? How has this changed over time?

Poor temperature control is today implicated in 44% of food safety failures, according to a Europe-wide study by the FAO.[204]

Figure 10: Contributing factors involved in outbreaks 1993-1998



Source: Food and Agriculture Organization of the United Nations (2002)

[201] Chan, K. F., Le Tran, H., Kanenaka, R. Y. and Kathariou, S. (2001). Survival of Clinical and Poultry-Derived Isolates of Campylobacter jejuni at a Low Temperature (4°C). *Applied Environmental Microbiology*, 67(9): 4186-4191
[202] Altekruse, S. F. and Swerdlow, D. L. (1996). The changing epidemiology of foodborne diseases, *Am J Med Sci*. 1996 Jan;311(1):23-9
[203] Hedberg, C. W., MacDonald, K. L., Osterholm, M. T.. Changing epidemiology of foodborne disease: a Minnesota perspective. *Clin Infect Dis* 1994;18(5):671-82
[204] FAO/WHO (2002), *Statistical Information on Foodborne Disease in Europe: Microbiological and Chemical Hazards*, paper presented at FAO/WHO Pan-European Conference on Food Safety and Quality, Budapest, Hungary 2002

Note that this definition includes not just inadequate refrigeration but also inadequate cooking, reheating or the maintenance of food at a sufficiently hot temperature. The type of 'temperature misuse' varies by location – in Mediterranean countries the main contributing factor is inadequate refrigeration, whereas in the Northern countries, the heating-related activities are more significant.

According to a study by the UK's Food Standards Agency (FSA), *'inadequate storage conditions',* which will include poor refrigeration but not inadequate heating (which is in a separate category), account for 22% of all biological breakdowns in food safety. If the 'unknown' category is excluded, the figure rises to 27%.[205] It is certainly the case that if the food system we have today were to make less use of refrigeration, the number of temperature-related food poisoning outbreaks would grow. On the other hand, the food system we have today is only possible *because* of refrigeration.

The vast majority of breakdowns (63%) occur during the course of preparing, displaying and selling the food (as opposed to the production or transport of raw ingredients) and the main establishments associated with these breakdowns are restaurants, hotel and other commercial catering outlets. Incorrect storage and inadequate heating are the key areas of food safety concern and the definition of incorrect storage will include poor refrigeration and refrigeration-associated practices.

There is a large body of literature dealing with food handling practices in commercial settings.[206,207,208] While ideally, this paper would look closely at the role of refrigeration and associated food handling practices in these premises and how the importance of refrigeration in relation to food safety has changed over time, this unfortunately has not proved possible in the time available.

However, as regards food safety, the home is also an important stage in the food supply chain. It is examined a little more closely here and in the subsection that follows.

According to the FAO study[209] the private home is responsible for over 40% of outbreaks. This is the average for Europe as a whole and clearly the incidence will vary by country. A Dutch study puts the private home's contribution to outbreaks even higher at 30-50% of incidences.[210]

For England and Wales, a paper by Redmond and Griffith[211] cites research estimating that 12-17% of outbreaks of foodborne disease originate in the home while the FSA study (already highlighted) finds the home (defined as consumer handling and consumption) to be responsible for 42% of all problems. This 42% covers all biological, chemical and physical breakdowns. When it comes to biological hazards

[205] *Breakdowns in Food Safety: Final Technical Report*, Food Standards Agency Project HO 1004, 2005, Table 26, section 6
[206] Clayton, D., Griffith C. J. (2004). Observation of food safety practices in catering using notational analysis. *British Food Journal*, 106(3): 211-227
[207] Sagoo, S. K., Little, C. L., Griffith, C. J. and Mitchell, R. T. (2003) A. Study of Cleaning Standards and Practices in Food Premises in the United Kingdom. *CDR*.\6 (1): 6-17
[208] Coleman, P., Griffith, C. J. and Botterill, D. (2000). Welsh Caterers: Food Safety Beliefs and Attitudes. *International Journal of Hospitality Management*, 19: 145-157
[209] FAO/WHO (2002), *Statistical Information on Foodborne Disease in Europe: Microbiological and Chemical Hazards*, paper presented at FAO/WHO Pan-European Conference on Food Safety and Quality, Budapest, Hungary 2002
[210] Oosterom, J. (1998) The importance of hygiene in modern society*, International Biodeterioration & Biodegradation,* 41 (1998) 185-189
[211] Redmond, E. C. and Griffith, C. J. (2004). Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal,* Vol. 106 No. 8, pp. 581–597

(where temperature control can be a contributory factor), consumer handling and consumption is only responsible for 11%.

It would be interesting to know how this has changed over time and in particular how the uptake of refrigeration both domestically and commercially has affected the pattern of food poisoning and relative contribution of incidents that are temperature related. Unfortunately, this is a question that is impossible to answer and, as already highlighted, the types of food we eat and how we buy and prepare them will also have a bearing on temperature-related illness.

c. Household behaviours and practices

What contribution today does inadequate temperature control make to the incidence of household-related food poisoning relative to other household practices with a bearing on hygiene (including hand washing, cross contamination and so forth)? How has the knowledge of what constitutes good hygiene, and its practice, changed over time and how has this affected the incidence of foodborne illnesses?

Our knowledge of food hygiene and, crucially, the extent to which we put this knowledge into practice has a critical bearing on the safety of our food. Elements (apart from proper storage) include handwashing, cooking food properly, covering food and – a major potential hazard area – avoiding cross-contamination.

In the home, cross-contamination – wiping dirty hands on tea towels, not washing chopping boards properly and so forth – has been identified as a major cause of risk. In one survey of food preparation practices, 80-86% of all unsafe food-handling behaviours implemented during food preparation sessions were associated with cross-contamination.[212] This study looked just at behaviours during the course of preparing food and of course if all food-related practices were examined (including storage) then the relative importance of cross-contamination might be lower.

It would be very helpful to know how food safety practices have changed in the recent fifty years or so.[213] Are we safer now than we used to be and what is the correlation between food safety practices and the incidence of food poisoning? Unfortunately, the literature on public food-safety awareness is still relatively new[214] and so this sort of longitudinal analysis is not possible.

Several studies looking at practices with respect to different age groups, however, do find that today's elderly people are more likely to practice *'unsafe food-handling behaviours'*[215,216] than younger age groups, reflecting the habits and practices that they were brought up with.[217] It would appear to follow that younger generations will be safer in the way they handle food than older generations.

[212] Redmond, E. C. and Griffith, C. J. (2004) Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal,* Vol. 106 No. 8, pp. 581–597
[213] Attitudes to hygiene in general were pretty poor in the nineteenth and preceding centuries so it is probably safe to say that the importance of temperature control was minor relative to other prevalent hygiene malpractices
[214] Chris Griffith, University of Cardiff, personal communication, November 2006
[215] Torstar, M. J., Steenbekkers, L. P..A., de Maertelaere, N. C. M. and Nijhuis, S. (2005) Food storage and disposal: consumer practices and knowledge, *British Food Journal*, Vol. 107, No. 7, pp. 526-533
[216] Redmond, E. C. and Griffith, C. J. (2004) Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal,* Vol. 106 No. 8, pp. 581–597
[217] Chris Griffith, University of Cardiff, personal communication, November 2006

However this is not quite the case. One of these studies showed that while older people tend to prepare food unsafely, so do young professional men.[218] Interestingly, young men were also more likely than other groups (older people and the 'safest' group – mothers with young children) to place responsibility for the safety of their food in the hands of the manufacturers rather on their own practices. It is hard to know whether this reflects a general societal trend towards offloading responsibility on 'Them' or whether it just says something about young men. There will probably be as many differences in the practices of individual elderly people as there are between elderly people and young men. One might speculate however, that if cooking skills continue to decline then we may continue to place ever more responsibility for food safety on manufacturers and retailers. This could, conceivably, stimulate the further tightening of regulations and standards, which may in turn have implications both for refrigeration and packaging use.

One might therefore surmise that if we as a society were to know more about food (how to cook it, how to know when it is unsafe to eat and so forth) and to take more personal responsibility for the safety of what goes into our mouths, then the need for more stringent regulation could be eliminated. This however contradicts the observation above that older people handle food less safely than younger people, including young men: this is because they have developed intrinsically risky habits despite their 'knowing about' food (the research does not, incidentally, explore whether people who practise unsafe behaviours do indeed end up getting sick). The more risky behaviour of older people may simply reflect the lower levels of food safety awareness current when they were young. It is possible that if this now older generation were also not to 'know about' food, they would be even more at risk of food poisoning than they are now. In future years we may see a new older generation of people who are unsafe in the way they handle food because they do really know what to do with it and how to handle it, in addition to which they do not feel responsible for their own personal safety.

d. Food types

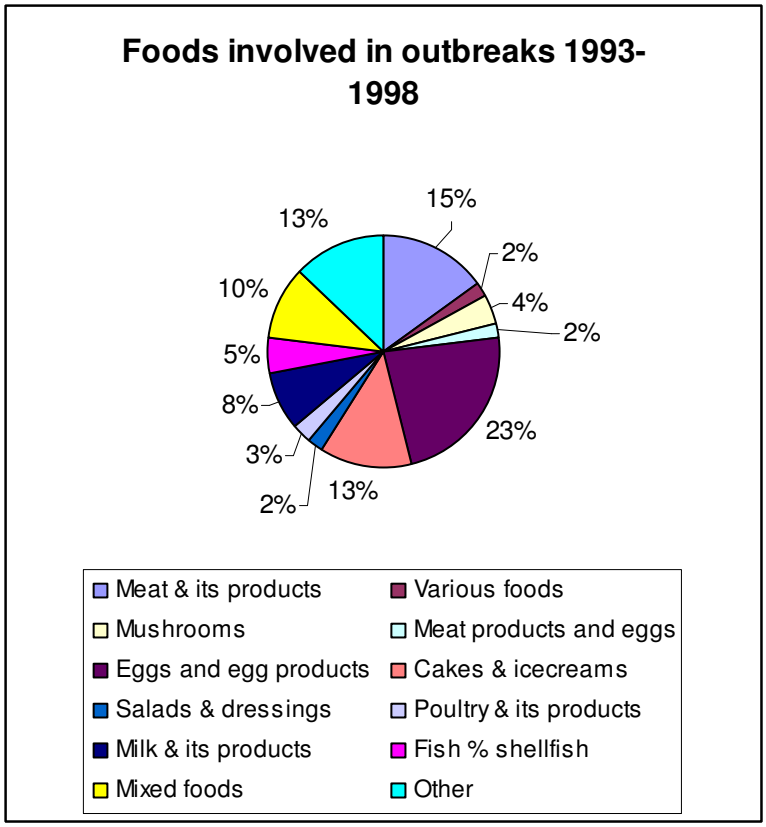
Which are the main foods implicated in food poisoning incidents?

The FAO study highlighted looks at the main foods implicated in food poisoning outbreaks across the EU and finds (see Figure 11 below) that foods of animal origin are responsible for the majority: 56%. This is likely to be a conservative estimate since dairy products will feature in the 'cakes and ice-creams' category as well as, possibly, in the 'various foods' and 'other' categories.

For the UK specifically, the FSA study finds that for biological 'breakdowns' in the supply chain, products of animal origin account for 55% of the total. This does not include 'desserts' many of which will contain eggs or a dairy product. If the category 'unknown' is excluded (these are incidents where the food type has not been identified although of course it could well include animal products), the contribution of meat dairy and other animal products rises to 75%.

[218] Redmond, E. C. and Griffith, C. J. (2004). Microbiological and observational analysis of cross-contamination risks during domestic food preparation, *British Food Journal*, Vol. 106, No. 8, pp. 581–597

Figure 11: Foods involved in outbreaks 1993-1998



Source: Food and Agriculture Organization of the United Nations (2002)

Steve James of FrPerc at the University of Bristol[219] reports on a study[220] that examines the occurrence of sporadic salmonella food poisoning in relation to food consumption and food-handling practices, opportunities for cross-contamination and refrigerator temperature control. The study, which looks at 99 households in South East Wales, finds that the purchase and handling of eggs and chicken were the most significant risk factors. Refrigerator temperature control was significant, even though on average refrigeration temperatures tended to be higher than recommended. Of course, the fact remains that all households in the study had refrigerators, even if they did operate at a high temperature. It is possible that that in the absence of any form of refrigeration at all, temperature-related food poisoning would be an issue.

e. Globalisation

How have globalised supply chains affected the nature and the geographical spread of food safety outbreaks?

The contribution of longer supply chains to food poisoning outbreaks during the Victorian era has already been noted above. More recently, both the rise in food poisoning during the war years and the outbreak of salmonella poisoning in the 1980s are the consequences of lengthened distribution systems and mass production. Other contemporary examples such as BSE, the Sudan Red colouring contamination and

[219] James, S. J. *Developments in domestic refrigeration and consumer attitudes*, Bulletin of the IIR, No 2003-5. See http://www.iifiir.org/en/doc/1051.pdf
[220] Parry, S. M., Palmer, S. R., Slader, J., Humphrey, T. Risk factors for salmonella food poisoning in the domestic kitchen – a case control study. *Epidemiol. Infect.* 2002;129(2):277-285.

the current threat posed by Avian Influenza are likewise the products of nationalised and indeed internationalised production and distribution arrangements.[221] In these cases refrigeration has *enabled* such long supply chains to develop. In other words, while refrigeration has had a critical role to play in preventing food poisoning, it has also made possible the dissemination of other forms of food-related illnesses.

f. Refrigeration and food poisoning: striking a balance

Refrigeration plays an invaluable part in ensuring that our food is fresh and safe enough to eat. Without refrigeration it is likely that cases of food poisoning would be far greater than they are now.

We have, however, also argued that the presence of refrigeration has in turn shaped the development of the sorts of foods we choose to eat, of the way we shop and of the way we cook. Refrigeration is now essential because the foods we now consume and the frequency with which we shop are predicated on refrigeration. In short, refrigeration has made itself indispensable.

We noted too that refrigeration has facilitated the development of longer supply chains which themselves have given rise to certain forms of food poisoning. Two other points are worth making. First, it is important to distinguish between the use of refrigeration to preserve the safety of our food, and its use to preserve food quality. The discussion of apple and potato storage above shows that for these foods, refrigeration is required to ensure our food conforms to quality standards as much as to preserve food safety. For meat and dairy products, however, refrigeration is arguably indispensable.

Finally we may need to ask ourselves in this area of life as in many others: how risky is *too* risky? How much risk in our society are we prepared to accept? This issue has been raised in other food-related contexts – the desire of some people to eat 'beef on the bone' during the BSE crisis as well as to buy unpasteurised milk or cheese. This is not to suggest that we should store our milk unrefrigerated but rather that we should have an eye to new developments both in food innovations and in new safety standards, and ask ourselves: do we need them? How do the various technological processes interact and interdepend and what might be the consequence of this be for energy use now and in coming years?

[221] This said, long supply chains are scarcely a new phenomenon. Colin Spencer (op.cit) notes that long-distance trade in foodstuffs has been a feature of British life for a thousand years and that in the Victorian era, food self sufficiency at 30% was considerably lower than it is today. By 1895, a third of our meat was imported (source: Victorian Agriculture, University of Guelph. See http://www.uoguelph.ca/ruralhistory/research/crowley/victorianAgriculture.html)

SECTION 7: TOWARDS A LESS REFRIGERATION-DEPENDENT FOOD SYSTEM

This section looks at what a less refrigeration-dependent system might looks like. It looks at what relevant policies and commercial or institutional practices either exist or could be developed which could foster a shift in this direction.

It is undoubtedly the case that while in the 1950s we were, as a society, far less dependent on refrigeration, at the same time such refrigerators as were in use were highly inefficient. The past may not, then, have used much less energy overall for its refrigeration. In order to reduce greenhouse gas emissions from refrigeration, we need to tackle both refrigeration dependence and refrigeration energy use. In other words the challenge is both to reduce our reliance on refrigeration and to reduce the impacts of those refrigeration systems that we need and use. Measures to improve the energy efficiency of our refrigeration system have already been discussed earlier.

This section looks at refrigeration dependence *per se*. It is a difficult issue to tackle, partly because we do not fully understand it and partly because we might not know what to do about it even if we did. It is hoped that his paper might at least provide some impetus for starting the discussion.

A less refrigeration-dependent supply chain would, *if waste is to be avoided and food to remain safe* require significant changes – in where and how we grow and transport food, in where and how we shop for it, and in how and when we cook it. This section briefly explores what some of the features of a less refrigeration-dependent food system might be, examines whether there are currently any policies seeking to achieve that goal, and raises some questions that may require further investigation.

Different types of food

Meat products tend to be the most refrigeration dependent of all foodstuffs.[222] A reduction in our consumption of these (and possibly dairy products too) would reduce demand along the whole of the food chain for refrigeration. Importantly, the rearing of livestock for meat and dairy products is a highly GHG-intensive process and so a reduction in our consumption of these foods will lead to far greater GHG reductions than those achieved by reduced refrigeration alone.

A shift away from chilled, prepared foods will also reduce refrigeration dependence. For ready meals, there could be a trade-off between, on the one hand, the energy used to produce the ready meal, and to transport and retail it, refrigerated, to the consumer; and, on the other, the energy used by cooking an equivalent meal from scratch. However, as discussed earlier, reliance on elaborate, pre-prepared foods that are dependent on globalised, technologically sophisticated production and distribution systems may itself foster changes in expectation that are inherently energy intensive.

As regards fruit and vegetables, a shift towards the consumption of more seasonal and more 'robust' produce could also reduce emissions since it would reduce reliance on refrigerated imports. Robust produce tends to be less critically refrigeration (and packaging) dependent. As highlighted, much UK produce is stored commercially for later consumption and studies have suggested that the energy balance between in-season imported food and stored indigenous food is a fine one, likely to tip either way depending on various factors, including the efficiency of the production system, the

[222] *Defra food refrigeration – energy mapping exercise*, Mark Swain, University of Bristol, presentation given at FCRN seminar, Manchester, September 2006

mode of transport and the length of storage. The issue is examined[223] and discussed in more detail elsewhere.[224]

In general, foods lower down the food chain such as cereals and pulses tend to be less refrigeration dependent than those further up. While such foods may require long cooking times – a possible trade-off here – the technologies exist (microwave ovens and pressure cookers being domestic examples) to minimise energy use.

At present, there are no policies which seek to influence our consumption of meat and dairy, or processed foods. Defra has commissioned research[225,226] which highlights the environmental impacts of meat and dairy consumption but the implications of these findings have not been translated into policy.

Different notions of quality

If we are to reduce our dependence on refrigeration we may have to accept 'good enough' quality food; food which is perfectly safe to eat but which may, for example, be softer in texture (as for some fruits) or blemished. This of course flies in the face of current retailing practices and so far there are no signs that Government is even considering this issue.

Different ways of shopping

More regular trips to the shops, provided they are on foot, can make it possible for people to have smaller fridges (see a discussion of this below); for people living in rural areas where there are few shops within walking distance, so this is usually not an option. Clearly, this raises questions as to how we allocate our time between work, leisure, domestic and family activities.

It is possible that a shift by the public to daily shopping patterns could have an effect on retailers' delivery systems – they may need to deliver smaller quantities more frequently in smaller, less efficient vehicles. However since the total volume of foods the public purchases over the course of a week is unlikely to change, this is by no means certain. This issue perhaps require further investigation.

How do Government policies affect the way we shop? Its planning policies have certainly had an influence. The *laissez-faire* planning policies of the 1980s encouraged the development of out- and edge-of-town shopping centres, spurring the trend to the large weekly shop. Since then, new policy guidance[227] has sought to revive city centres and promote local access to shops and other services. As Section 4 above suggests, there may be some slight signs that we are beginning to move away from the weekly shop. The trends show that the supermarkets are on the whole

[223] Milà, i. Canals, L., Cowell, S. J., Sim, S., Basson, L. *Considerations in an energy consumption comparison of local versus imported apples*. Science of the Total Environment. Submitted.
[224] Garnett, T. (2006). *Fruit and vegetables & UK greenhouse gas emissions: Exploring the relationship*, Working paper produced as part of the work of the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey, 2006
[225] *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*, Final report to Defra on project no IS0205, Started by Silsoe Research Institute, completed (after SRI closure) by Cranfield University, 2006
[226] Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A., Mylan, J. (2006). *Environmental Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, Defra, London
[227] See for example Planning Policy Statements 6 and 7 and Planning Policy guidance 13; the predecessor of Planning Policy Statement 6 was the 1996 Planning Policy Guidance 6 and this explicitly sought to reverse the retailers' abandonment of the town centres

increasing their portfolio of smaller, more central stores, more rapidly than they are of larger store formats.[228] However the supermarkets also continue to expand their out-of-town portfolio, largely through extensions to existing stores. For consumers this means that they still have a very strong incentive to shop weekly in bulk, although they may also be 'topping up' this shop with trips to more local stores.

A move away from 24-hour shopping could also reduce the energy retailers use for both refrigeration and lighting. However, there do not appear to be any signs at all that Government is reassessing the relevant legislation. Indeed, with the recent loosening of restrictions on licensing laws, Government has shown itself keen to allow retailers to go further down the 24-hour route.

Different living standards

Keeping houses cooler would also improve the storage life of food, although this is a move that will only affect foods once they have reached the home. Many environmental organisations make the recommendation: 'turning the thermostat down just one degree can save xxx% off your energy bills' but such advice is given in order to reduce domestic energy use in general. Food storage does not form part of the argument. Moreover new building regulations[229] and the main thrust of policy recommendations seek not so much to reduce energy use by accepting 'lower' living standards but, through better design and insulation, to maintain the same temperature (or higher in the case of the 'fuel poor') at lower energy cost.[230]

As regards new housing developments; Government estimates that to meet demand, 200,000 new homes will need to be built each year across the country.[231] By 2050 a third of our housing stock could be new-build or built within the last forty or so years. Given current thinking it is certain that it is highly unlikely that these will feature larders; this is partly owing to space constraints but largely reflects the dramatic changes that have taken place in our living arrangements over the last fifty years. The option of no refrigeration is now scarcely an option at all.

Fridge sizes

However there may be some scope for reconsidering the size of our fridges. The domestic fridge is the end point in a complex, temperature-controlled supply chain. The more refrigeration-dependent foods we put in our fridges, the more refrigeration further up the supply chain this represents. Our refrigerators – how big they are and what and how much we put in them – serve as a marker of refrigeration dependence elsewhere in the supply chain. Moreover they tend to be determined not just by how much capacity is needed but also by the space that is allocated to them in fitted kitchen designs.[232]

On the face of it, it would be environmentally desirable for us all to shift towards purchasing smaller fridges. However it is not as simple as this: as we discuss below, there is a complex relationship between the size and efficiency of a fridge. A less

[228] *Working paper on planning issues*, Competition Commission, 2007 http://www.competition-commission.org.uk/inquiries/ref2006/grocery/emerging_thinking_working_papers.htm
[229] Building regulations: Approved documents, Part L. See http://www.planningportal.gov.uk/england/professionals/en/1115314110382.html accessed 23/11/06
[230] Boardman, B., Darby, S., Killip, G., Hinnells, M., Jardine, C. N., Palmer, J. and Sinden, G. (2005). *40% House*, Environmental Change Institute, University of Oxford
[231] Speech on climate change by Yvette Cooper MP to the All Party Parliamentary Group on Climate Change, on 7 November, 2006
[232] Chris Foster, University of Manchester, personal communication, December 2006

refrigeration-dependent food system would be one in which people's fridges were the *optimal* size for reduced energy use and the current labelling system should reflect this. This in turn could influence how much food containing 'embedded' refrigeration people buy.

It is important to stress that a less refrigeration-dependent system need not and should not be seen as a 'return to the past.' Our knowledge of, for example, food hygiene and waste management has improved, and these factors certainly need to provide a framing context for the development of a less energy-intensive supply chain.

The point we are trying to make here is that is important to distinguish between basic essential refrigeration and refrigeration that simply reflects the drive for convenience. Of course, where one draws the line could vary from person to person but as with all difficult issues, that is not an argument for not drawing it at all. Since reducing our reliance on some of the more refrigeration-dependent foods – particularly in the case of meat and dairy products – will yield emission reductions elsewhere in the food system, one might argue that refrigeration acts as useful marker for greenhouse gas intensity. As such, moves to wean ourselves off refrigeration dependence – and to halt its applications in the development of new products – could be seen as part of a package of measures needed to reduce food-chain greenhouse gas emissions.

An overarching context

A shift towards a less refrigeration-dependent food system cannot be undertaken in isolation from moves towards reducing energy dependence in all other aspects of life.

As such it is worth highlighting one possible policy approach which is currently being examined both by Government[233] and other institutions such as the Royal Society for the Arts (RSA)[234] and the UK Energy Research Centre.[235] This is the concept of the personal carbon allowance, or Domestic Tradeable Quota (DTQ). First developed in 1996 by the economist David Fleming, the concept is based on a 'cap and trade' system in which an overall sustainable allocation of carbon is divided up equally among the population. The carbon credits are 'spent' when individuals purchase energy in one form or another. At its most simple it would be linked to transport fuel and domestic energy use and as such would have a direct influence on people's use of refrigeration-related energy. People using less than their share of carbon could sell the surplus on the carbon market to people or businesses using more than their allotted share. In time, the scheme might be extendable to the purchase of goods (such as food) that have an embedded carbon footprint, although it could well be more feasible for emissions during the production of the foods themselves to be captured earlier in the supply chain by other schemes (including the CCA and a possible EPC). Higher embedded energy products (including refrigerated foods) would cost more.

[233] Roberts, S. and Thumim, J. (2006). *A Rough Guide to Individual Carbon Trading: The ideas, the issues and the next steps*. Research undertaken by the Centre for Sustainable Energy for Defra.
[234] Through its CarbonLimited project – see http://www.rsacarbonlimited.org/aboutcarbonlimited/whatispersonalcarbontrading/default.aspa accessed 23 November, 2006
[235] See http://www.ukerc.ac.uk/content/view/363/633 accessed January, 2007

SECTION 8: CONCLUSIONS AND RECOMMENDATIONS

Very roughly speaking, food refrigeration accounts for about 2.4% of the UK's greenhouse gas emissions. If one were to add on the (as yet) unknown refrigeration energy used by mobile refrigeration units, commercial cold stores and, importantly, the 'embedded' refrigeration in foods grown or manufactured and imported from overseas, then the figure could be at least 3-3.5%, perhaps more.

Refrigeration has yielded enormous benefits. It has made our food safer to eat and reduced waste. However, even in these areas, these gains have not been unalloyed. As with all technologies perhaps, it has created opportunities for new problems to emerge in just the areas which it assists.

Three per cent or more of total UK greenhouse gas emissions is no trivial contribution. Importantly however, refrigeration is also intrinsically linked to other technologies and cultural practices that are also, in themselves, energy intensive. The interactions among refrigeration, packaging, food transport, food product innovations and various socio-economic developments have helped create cultural norms and practices that are highly energy dependent. Technology and behaviour thus feed one another.

As such, refrigeration serves as a symbol, or marker of unsustainable energy use and unsustainable behaviours in the food system. Policies need to address, therefore, not just refrigeration energy *use*, but also refrigeration *dependence*. While energy-efficiency measures and novel technologies are important – indeed essential – they do not tackle the reasons *why* we need to use refrigeration (i.e. what it is about the foods we eat and the way we manage our lives that renders refrigeration necessary?); nor how refrigeration has catalysed additional developments in the food supply chain that have damaging consequences for greenhouse gas emissions.

Recommendations

Some initial suggestions for further research and action are as follows:

- Collaborative action by Government departments and industry to improve the energy efficiency of refrigerated transport, based on existing knowledge of best available technology.
- Action by users, suppliers and manufacturers of refrigeration technology to overcome systemic inertia and to ensure that the best available technology becomes more widely adopted and manufactured.
- Supermarkets and other food and drink retailers to reassess the extent to which they use refrigeration 'unnecessarily' in store and to seek ways of reducing its use.
- Supermarkets and other food and drink retailers to act as 'choice editors', helping to move consumers away from products that embody high levels of emissions due to refrigeration and other aspects of the supply chain.
- Retailers of domestic equipment to act as 'choice editors', stocking only the most efficient equipment.
- Research to quantify the embedded refrigeration energy in imported foods: this should be undertaken as part of a general research effort to quantify embedded greenhouse gas emissions from imported food along its entire life cycle.
- Research to investigate the nature of the relationship between choice, variety and the environmental impact of the food chain. Since the goals of more choice, total consistency and ubiquitous supply and availability are at the heart of the food

industry's business model, and since at the same time the industry is being asked to reduce its greenhouse gas emissions in line with national level reductions, then we need to know how this relationship works.

- Research to examine the interaction between technological developments and changing behavioural norms. So far policy attention has focused heavily on encouraging industry to adopt more energy-efficient practices and technologies. While Government is starting to define a sustainable consumption agenda, we need to understand the relationship between technological and behavioural change and analyse what we need to do to develop sustainable interactions between the two.

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APPENDIX: CHANGING REFRIGERATION DEPENDENCE IN OUR LIFE TIMES

The following accounts have been provided by friends, family, colleagues and their families and friends. They were asked for their memories, growing up here or overseas, of how their families stored food and where, how they shopped for food, whether food was delivered and for any other details which might have a bearing on food storage. Some of the memories stray into other areas but since they are so interesting it seemed a shame to edit them. These are their accounts are set down, almost as-is, in roughly chronological order.

Australia, born 1915

'*This is from conversations I had with my Nan and my Dad. It's about Nan's refrigeration practices in the 1940s. It's patchy because Dad was only five when they got a fridge and so doesn't remember much. Nan is still very sharp considering she is 91, but I couldn't clarify everything because of the time it was taking*. '

From 1942 to the mid 1940s, Nan and Pa (grandpa) lived at Narradin, 500 miles west of Sydney. From the mid 1940s to the late 1940s, they lived at Yanawah, 15 miles west of Young. I haven't looked on a map to see where Young is in relation to Sydney.

During this period they had no fridge. Both places are rural, and Yanawah was particularly tiny and isolated. At Narradin in the summer it get to over 100°F, and wouldn't cool down much overnight. It was colder in the winter.

They had a wire container, over which Nan would drape wet cloths. It is dry out west and so evaporative cooling would cool down the container, into which they would put milk, butter and meat. They had to cook the meat and eat it very quickly. Sometimes Nan would buy salted meat, like bully beef, other times she would preserve it herself – boil it with onion, salt and a bit of sugar. At Narradin they had a local store, which was very convenient to get to. They would buy perishables every few days, as they couldn't keep them long. At Yanawah, they had their own cow and chooks (chickens). Most people out west during the war years had to look after themselves, and many were on the land and so were able to have cows and chooks.

They didn't have a separate room for food, but they did have a pantry. Nan mainly kept tins in there. Their accommodation was very basic, the "bare essentials", as Nan put it.

When they moved to Yanawah, they applied for a fridge. (Pa was a teacher, so I guess they must have applied to the New South Wales education department.) At that stage they had a toddler (my Dad), and another baby on the way. Apparently there were other 'more deserving cases', so they didn't get one until they moved to Naamaroo, in the late 1940s.

They didn't get much fruit, just enough for their weekly needs. Occasionally someone would give them surplus, e.g. a bucket of plums, and Nan would make jam. It was difficult to make preserves because it was so hot. They had a tiny kitchen with a big old fuel stove, and in the summer it was so hot and they didn't want to heat up the house any further! In the winter it was OK, but I suppose they wouldn't have had much to be able to preserve then anyway.

At Narradin the people had ice-cream parties at Christmas. They would make really rich ice-cream, with cream, eggs and ice, in a churn, and the men would turn the handle. They had to get ice in from Lake Cargelico, twelve miles away. Everyone would sit around waiting with their bowls. After this, they moved to Naamaroo, on the outskirts of Young. They got their first fridge here, a kerosene cold-frame fridge, which had a tiny freezer compartment – enough for ice cubes. They had no electricity. They were able to do their shopping in Young, a reasonable sized town and so things were much easier then.

Ken, born 1932, urban

We first got a fridge in 1964. Before then, food was kept cool in the larder which was one metre square and two metres high. The larder faced north so the sun never shone on that part of the house. The larder had a shelf (tiles on wood) three feet high and this kept food cool. Milk had three cool situations:

a. In the larder
b. Outside in a bucket which was half filled with water and covered with a flannel-type cloth which hung in the water. The water evaporated from the cloth and kept the milk cool.
c. In an 'osokool.' This was a thin metal mini-box with a kind of porous polystyrene. You put milk in the bottle, poured water into the hollow on the top; the water evaporated and you had a cool interior.

We got a freezer when I got married (1961). It was all 'Buy a freezer and save on buying a whole lamb. Freeze it and save money.' My wife and I said 'No!' Eventually the freezer was wonderful to pop odd things in – not spending every hour in the garden to fill it.

As for deliveries: from 1934 to 1961 we had milk delivered daily. The local shops were excellent (my mother refused to go into Tesco – 'a tatty little cheap store!'). We probably shopped daily. We never stored food. It was tins during the 1939-45 war. Our area was urban.

Richard, born 1935, Belgian Congo (of British parents)

Growing up in the 1940s we had a meat safe and an ice box. Later we got a fridge – no freezer, just an ice tray.

I think we had an ice-cream maker but I don't know how it worked. Later, in the 1950s, living in South Africa, everyone had fridges but I don't remember anyone having freezers. When I first went to the USA in 1963, the first thing that struck me was the amount of ice in all drinks.

When I came to London in 1956, living in digs, we kept the milk outside on the window-sill – no fridge in digs.

Bonnie, born 1940, Toronto

To begin with we had an icebox, the refrigerator's predecessor. A block of ice was placed in the top compartment, food and stuff in the bottom and, beneath that, there was a space for the pan, which held the water from the melting ice. The water dribbled down through a pipe and, of course, you had to be pretty quick about emptying it or you would end up with a nice puddle on the floor – which happened pretty often. The ice was delivered in 25 lb blocks as I recall and we used to get in trouble for (a) 'playing hookey on behind' (cadging a ride on the back of the truck) and (b) sucking on slivers of ice that fell off when the iceman separated the blocks. The latter was really dangerous because polio was rampant in the '40s. No health and safety then. I think we acquired a refrigerator around 1950.

When we lived in Long Branch (also in the late '40s), milk and bread were still delivered by horse and cart. Indeed I just have to think about it and the smell of horse and fresh bread comes wafting into my memory.

We didn't have a freezer till the late '50s and then it was just part of the refrigerator.

Roland, born 1942, near Croydon, suburban

My family first got a fridge (the gas-powered absorption/desorption type, not electric!) in about 1958. We had a separate stone-floored 'pantry'. In the summer, we used porous terracotta covers which were kept damp so that they cooled by transpiration and evaporation. Milk and bread were delivered regularly (by horse-drawn cart in the 1950s, then by electric trolley).

My parents didn't have a freezer compartment until the 1970s – I first met freezers when I emigrated to Canada in 1967.

Andrew, born 1943, rural

Back in the '50s, before we had a freezer, we used to do the following:

- Bottled fruit (plums, pears, raspberries) (can't remember if we kept tomatoes this way).
- Preserved eggs in 'water glass'.
- Preserved runner beans in salt (supplied in big blocks wrapped in paper – you scraped the salt off the end of the block with a knife).
- Kept a pig until the end of food rationing – my father used to cure the bacon himself and bits and bobs were made into brawn.
- Hung game in an outdoor meat safe in the cottage courtyard.
- When my father caught a salmon it was transported in a special bag made, I think, of reeds. You can keep a salmon for a few days this way and it gets better in the same way that hung game is tenderer and more flavoursome.
- Made jam and marmalade.
- Made clotted cream (occasionally).
- Cream came in jam jars from a farm in Ryton – I used to collect it on my bicycle.
- The Condover shop used to deliver groceries, including fresh bread which they baked.
- The butcher in Dorrington (Mr Sadd) also used to deliver.
- Surplus garden produce was sold to the Shropshire Produce shop in Shrewsbury.

We first had a fridge after mains electricity was connected (1952-53 or thereabouts). The freezer came a few years later. Before electricity we had an Esse stove (a kind of Aga) which ran on anthracite. After electricity we had the kitchen re-done and used a large American electric stove.

Tricia, born 1944, Nottingham

I did not have a fridge until I was 16 years of age when my brother went to work for Electrolux and got one for mum. We got a freezer when I got married at 28. Before then, food was stored in the pantry; cheese and other perishables on a marble slab and we also had a meat safe with the mesh front to keep the flies off. The house would have been pre the Second World War. Bread was delivered daily. Milk was delivered in bottles every day and in the winter was left outside to keep cool and it formed ice out of the top and inside which was much loved on the cornflakes. I remember salting of runner beans and pickling of onions, red cabbage, etc. Game was hung in the outhouse before it was plucked, drawn and singed by mum and then was ready for cooking. Vegetables were kept cool either in the pantry in summer or the outhouse in winter.

We bought our food from the Co-op. Dry goods were sold in paper bags and weighed out from big sacks around the shop – sugar, flour, different sorts of rice, biscuits, etc. No dry goods were sold pre-packed. Bacon and cheese was bought from the dairy counter all cut to order and bacon was sliced by a bacon slicer. You had a book which you took to the Co-op and it was delivered if wanted by a boy with a pannier on the front of his bike. You paid once a week and got Co-op dividend as you

had a Co-op number. There was a shop selling fruit and veg and wet fish. Watercress was in a bucket of water and sometimes you could see small fish in it, so you knew it was from a pond. There was also a butcher and a baker. At Christmas time, as ovens were small, we used to take the turkey to the baker's oven and he would cook for our area. There was a beer-off (off licence) and you could buy a jug of beer. We sometimes had one and were allowed a shandy sometimes on Sundays.

We only had a back yard, no garden apart from where we pulled up the bricks and planted an acorn which grew into a big oak tree, most inappropriate. So we could not keep chickens or grow your own veggies, etc. The game came from what Granddad used to pick up when he was driving about as a commercial traveller. You could only pick up what someone else had knocked over (country law). We used to go blackberry picking and mother made jam and also mushroom picking. Just after the war before fresh fruit from abroad became abundant we had dried fruit – bananas in particular.

Maria, born 1945, Cyprus

My parents' house was middle class. As long as I remember, at least from the age of six when we moved to our new house, we had a fridge (1951). That fridge lasted us for 45 years. It had a small freezer compartment.

In our neighbourhood the majority of people did not have fridges. We sometimes took pitchers of iced water to the neighbours who lived opposite. The treat of the day was the ice-cream man who wheeled his ice-cream making contraption (a huge thermos) on a barrow. Vanilla with strawberry sauce for 1 penny in 1954. Also we had fruit vendors selling cold watermelon slices or prickly pears. They were kept cold in ice. We had a street vendor selling ice-cold airani (salty lassi).

Meat was bought daily or when needed. Water was in an earthenware pot which was kept in a shady place to cool. During picnics on the mountains you kept your beer and watermelons cool in the stream.

My aunt Theano who lived in Famagusta definitely was more primitive than us. She had a petrol-operated fridge and she washed the dishes with the chaff of the corn and barley.

On Troodos (the mountain range in Cyprus), at the Chionistra peak, there was a large hole in the ground where the snow was kept and used in warmer weather. I do not know who was entitled to that treat; probably the governor who had a summer residence on Troodos.

You could also buy ice from an ice-making factory. When we travelled to our shack in Kerynia we used to stop on the way and buy a slab of ice. That would be kept in the ice box and would last us a whole weekend.

However, there is the general belief in Cyprus that if you drink cold water you catch a sore throat...

Derek, born 1947, suburban

Early childhood was in what I would now perceive as a lower middle-class suburban neighbourhood between Langley and Slough. An agricultural area when my parents grew up in the early 1900s, it had become progressively more developed between the wars and became a London slum overspill area immediately after World War Two. Our house was built in the 1920s.

A refrigerator didn't enter our lives until about 1956, by which time we had moved into a new-build house in the smart suburb of Beaconsfield (different world, different life, cars, supermarkets, etc.). This house had no larder or anything like that. In the old house, the larder was been the place for perishable foods. I don't recall any special gadgets or purchase of ice – I suppose I can't have noticed what my mother

did in summer, if she did anything unusual. We had no home-grown foods but groceries were often delivered (you went through your list with the grocer, who subsequently brought the stuff round) and there was also a van that came round the neighbourhood selling vegetables and fruit. I don't recall whether or not it was possible to order by telephone. We had a 'pig bin' for certain types of waste, which was collected, I suppose weekly, by the 'pig man'. I often wondered where it went – I suppose there must have been a local pig farm. Milk was delivered daily, but I don't think the milkman sold anything other than milk and cream. A newspaper was also delivered daily. In my early childhood there must have been shortages since rationing would still have been in place, but I was too young to remember or be aware of any of that. With hindsight I realise that everything must have been seasonal, but I don't think I would have noticed.

Meat was on the menu most days, and my mother's menus were very predictable: Sunday lunch a joint, eaten cold on Monday, made into mince on Tuesday. More meat on Wednesday – maybe sausages or chops, maybe a soup on Thursday. Friday was usually fish, and Saturday a casserole (probably beef?) at lunch time with cold ham or smoked haddock on Saturday evenings – prawns as a special treat occasionally.

Mother did not make jams and pickles, etc. We never had ice-cream at home, but frequently had a Wall's or Lyons vanilla ice or choc bar when travelling around.

We had a local small grocery shop up the road where we would buy odds and ends most days, and then a larger one in the village where my mother would place her weekly main order for delivery.

All food shopping was done within a 1.5 mile radius of home. For clothes and other things my mother preferred Windsor – about 20 minutes on the bus. Maybe twice a year she would take the train to London and shop in Oxford Street – materials and patterns from John Lewis, Christmas shopping in Harrods and Selfridges.

We were a fairly traditional family so my father was not involved in food purchase or preparation or, in fact, anything domestic at all. We had a woman who came in and cleaned and sometimes looked after my sisters and me, but generally my mother did all the housekeeping and cooking.

Alison, born circa 1948, urban

I can remember having this huge walk-in larder where everything seemed to be stored, every available shelf space being used, I especially remember the top shelf for cooked meats, in particular the remains of the Sunday joint, ready for sandwiches.

One of my fondest memories was going to the Home & Colonial store with my mum every Saturday and buying cooked meats, especially if visitors were coming; my favourite being luncheon meat, I loved it and still do (although the taste isn't the same anymore…or maybe it's my taste buds that have changed!).

I don't remember having a fridge in the house until I was about eight or nine years old and my parents' first freezer didn't appear until Dad retired, late '70s. For the most part it wasn't important as he was a master butcher and therefore brought all our meat, eggs, etc home with him every day fresh. This applied to most things, e.g., bread, milk and veg as his shop was along a parade and it was just as easy for him to bring all these things home at the end of the day. I can't every remember having milk delivered.

I can remember my dad was very friendly with the baker (next door to his butcher shop) and like all shopkeepers, they would help each other out. Another great memory of my childhood (1950s) was that in the summer we ate lots of fresh salad and dad's friend 'Mr Baker'... (*this sounds like a child's story book!!*) would make sure Dad brought home a freshly baked HOT loaf…….*Mmm. I can taste it now.*

For the reasons above, apart from special occasions I can only remember the Saturday mini-shop to Home & Colonial in Chiswick, never a big shop except for Christmas and other special occasions.

I was born and brought up in London until I was 21 (early '70s), when I got married and moved to Woodley, Reading. First priority on our "buying" list was a large freezer which for us back in 1971 was a necessity as my mum/dad would come to Reading every week to visit and fill the freezer with legs of lamb, beef joint, etc, so although like every newly married couple we didn't have lots of money, we always had very good, expensive meals.

Chris, born c. 1948, rural

I was about seven when we first got a fridge. I remember my gran had a freezing cold larder with a stone ledge where she kept food, etc. She had a meat safe which was a wooden box with perforated metal sides to let the air in and other nasties out. We got a chest freezer when I was twelve and it was kept in an outhouse – in those days you bought sides of beef, etc., and worked your way through all the weird and wonderful cuts and offal!

Most houses had a larder for storing foodstuffs, with a cold slab for perishables, but by the time the Second World War was over and new houses were built, the stone was done away with.

We lived in a very rural area from me being eleven and the local farmers sold a lot of their produce at the door. We had a small Co-op in the village and most of our shopping was done there as and when needed. Local people started going round in vans selling the things that were not available in the village and occasionally we would venture into Leeds, our local metropolis – usually as a treat at Christmas time or for new clothes, etc. It wasn't the norm to be able to buy clothing, etc., other than by going into a large town or city.

When I was eleven, we moved into a very rural village in West Yorkshire (a pit village). We had a large bungalow with lots of land. The orchard produced quite a lot of fruits and I have strong memories of sleeping in my room with the strong smell of stored apples under my bed. My dad (a headmaster) was a bit of a 'Good Life' type. We wrapped apples in newspaper and lined them up in trays to store for the winter. He also bought an old cast-iron washing mangle so that all the damaged apples could be crushed and made into our own cider. We kept bees and each year had a very sticky kitchen as we spun the honeycombs to extract the honey. This was stored in jars for our own use and we even tried making mead. We grew most of our own fruit and veg plus a few more exotic things in the greenhouse. I remember my father growing some things under an old aeroplane cockpit cover.

Judy, born 1949, urban

We moved from the centre of London in 1952 when I was three. We moved into a Victorian semi-detached house on the outskirts of Ipswich – the town boundary being the wall between us and the other half of the semi-detached. So it was semi-rural. With the house came a third of an acre of uncultivated land. The house had no toilet or bathroom and Mum and Dad had an extension built off the then kitchen and I recall that this also included a larder – no fridge, and domestic freezers hadn't been heard of at that time. Having lived in London all their lives I suspect Mum and Dad had no prior knowledge of gardening but they cultivated every bit of the land they had purchased.

We had 100 chickens (bought in as day-old chicks) and sold the eggs to Framlingham Egg Packers. The egg packers came once a week to collect the eggs, which had been stored in the off-kitchen larder.

We had an orchard at the very top of the garden which was guarded by geese.

The rest of the garden was put to vegetable and fruit growing, which Dad did most of (despite having a full-time job) and mum grew flowers. My brother and I helped out a lot – well I think we helped! We had a blackboard by the front gate and, daily, Mum would chalk up a list of things we had for sale. Apparently the profits paid for our seaside holidays to Eastbourne.

Left-over food went next door because they had a pig sty and a couple of pigs.

I can remember lots of things being delivered. Milk was delivered daily and it came in pint bottles but it was always given to my mum – it was never just left at the door. Bread was delivered every other day by a gentleman on a bicycle who came to the door with a large breadbasket and we could choose what we wanted out of that. The butcher also delivered. I think he came just once a week on a Saturday. He brought the meat ready jointed in a basket and, again, we got to choose what we wanted from the basket. Having lots of chickens we sometimes ate one! Sometimes an ice-cream man would come on a three-wheeled cycle and we would buy blocks of ice-cream from him.

We didn't bottle fruit, we canned it… I can remember Mum and Dad investing in a canning machine. It was a major event when we had a canning session. The tins were about twice the width of present-day soup cans and about half as tall again and were re-usable. They were filled with fruit from the garden and then the cans were sealed using a rotating press arm. The cans were then put into Mum's gas-powered clothes boiler for about half an hour. After they had cooled we labelled them and put them on the shelves in the off kitchen larder for use through the winter months. I was always allowed to fill one can with whatever I liked. I always filled it with lots of different fruits. We had tinned fruit every Sunday.

We did make jam and I still have Mum's jam pans. Raspberry and strawberry jams were my favourites. We didn't salt vegetables. I cannot remember ever not having fresh vegetables out of the garden, even in winter. That was what Sunday mornings were for – heading up the garden with the wheelbarrow.

Going out to do shopping seemed a rare occurrence. We had a Co-op within walking distance and also a 'flour' shop. Here they would grind the flour for you and put it into a stiff brown bag and would also weigh out blue bags of sugar. We had a corner shop where Mum would buy butter. They would slice rashers of bacon for her.

We moved to Lincolnshire in 1959 to a village called Heighington – five miles outside Lincoln. Those families in the centre of the village did not have running water in their homes and took buckets to roadside water pumps which were dotted around the village. Gas had not come to the village either – and still hasn't as far as I know.

Our house was not very old – probably built around the early 1940s. It had a purpose-built larder where we stored vegetables. It was very cold. We did not have a fridge until the late 1960s and even then it did not have a freezer section.

Everything was available in the village or it was delivered. We had our own butcher who slaughtered on the premises. In addition a van would come out from Lincoln twice a week from Curtis's the butcher. The van would stop at varying places round the village and people would go out to it. It also had a selection of cakes for purchase. Milk was delivered daily in pint glass bottles from one of the farms. Several local farms made their own butter which came in carefully shaped one-pound (weight) slabs each 'patted' with the farm's design on the top. The Co-op delivered bread daily to the door, if required. The 'Fish Van' from Grimsby delivered every Wednesday. The choice he had was not limitless – it just depended on what the fishermen had sold him at the docks. Again he would stop at points around the village and people would go out to him. We grew our own fruit, vegetables and had our own fresh eggs (reduced to six chickens by now) and also purchased from people around. Friday night was fish and chip night because a chip van came round – how it never caught fire I don't know.

Phil, born 1950, rural

I was born in 1950 and my most relevant memories… come from the time when my younger sister and I with both parents lived in a small village about three miles from Peterborough in East Anglia. We were a middle-class family.

We did not have a fridge until I was about twelve or thirteen years of age, and even then it was more for novelty, i.e. making ice and ice lollies, temporary storage of ice-cream, cold drinks in summer, etc. Instead, food was kept in the pantry which was a separate small room in the kitchen. The house was brand new when we moved in (1954) (three bedrooms, detached) but built on concrete with a tiled kitchen/pantry floor and although there was a coke stove in the kitchen the pantry was cool (and fitted with a small window). There was no central heating so apart from coal fires in the lounge and dining room, portable electric heaters were used in the bedrooms (and everyone always wore hand-made knitted pullovers or cardigans in the winter). At that time, and for a long time, there was no need for a freezer and so it would be 1970 or later that this appliance arrived.

The village had a small corner shop for essentials but we did not use it much except for sweets and things we had run out of. Milk was delivered once a day by electric truck. Bread came twice a week in a van. Meat also came once or twice a week delivered by horse and cart. On Saturdays, we used to go into town to shop for the main supplies. The traditional, specialised shops were visited where you waited to be served since I do not remember the general supermarket with self-shopping arriving until I was ten or eleven. All food was kept in the pantry.

We also had a vegetable garden where my father grew potatoes, brussel sprouts, lettuces, etc., which were picked when required. My mother was a good cook of basic English food. Cakes were baked frequently, puddings and jam made from seasonal fruits, and various things preserved in Kilner jars. Everyone tended to share each other's produce. I am not aware of anyone salting any food at that time.

Simon, born 1950

I am 56 and have had a fridge for only about ten years of my life, mostly in the 1960s. For most of the 1950s my family didn't have a fridge. The Sunday joint would be served cold on Tuesday, as shepherd's pie on Wednesday, rissoles on Thursday and by Friday there might still be some dripping for sandwiches.

Until two years ago I lived for ten years at Tinker's Bubble, a community of about twelve people in Somerset where no fossil fuels are allowed on site. The community has renewable 12-volt electricity and for the last five years has run a tiny 12-volt caravan fridge, but only during the height of summer.

The fridge is used for table milk, to keep culture for making cheese cool, and for occasional specialist items. No other foods are in it.

There is no problem with food going off. This is because there is access to fresh milk, vegetables and meat produced on site or nearby.

The milk from cows or goats is not chilled to below 4 degrees, but cooled to 10 degrees in a stream which is the correct temperature for making cheese. This is not a coincidence: English cheese-making methods were developed to suit English ground temperatures.

Even when milk is not used for making cheese there is an advantage in keeping it at 10 degrees. At below 4 degrees milk will keep longer, but when it does go off it tastes foul because a cool temperature favours spoiling bacteria. At 10 degrees milk will turn quicker, usually in 48 to 72 hours, but it turns to something relatively edible, depending what bacteria are around. It can sometimes turn to yoghurt. When I was on a dairy farm in India, yoghurt was made simply by keeping the milk in a cool (by Indian standards) room, and squeezing a lime into it.

While at Tinker's Bubble I kept pigs, and cured bacon in a cellar at about 10 degrees. This was satisfactory, though something a bit cooler might have been preferable. In winter a fridge is helpful for processing but obviously (since pig-processing has been carried on for centuries) not essential, though we were assisted by the fact that the meat comes chilled from the slaughterhouse.

In summer you need a fridge for processing a pig, though I dare say a pig could be slaughtered and processed in summer if you had cool stream water, a cool cellar and several people working on processing it.

Female, born 1953, rural

We did not have a fridge until I was about ten, which was 1963. I don't think we had a freezer until ten years later. We had a large pantry for storage and in there was a marble gantry for storing perishable goods as it was obviously cool. We also had an outhouse for storing home-grown produce. In the pantry we had a meat safe for fresh meat which was bought every day except at weekends.

Shopping was done on a daily basis. Milk was delivered daily. On a Saturday we had a local man who came round with a horse and cart to sell fruit and veg. My mother preserved all the produce grown in the garden by bottling or pickling.

Penny, born 1954, Plymouth

Yes, we had a fridge, and bought a freezer in approximately 1966. The house, which was built in the 1920s-30s (it had a bomb shelter in the front garden) had a larder. My grandmother's bungalow, which was built in 1957, also had a larder. The 1968 building regulations stipulated a 'ventilated food cupboard' – I don't know if this is still extant. Shopping trips were made 2-3 times a week possibly; we had shops at the bottom of the road so they were always there for emergencies. Delivery men came ever day of the week – milkman, Corona (fizzy drinks), butcher and greengrocer.

I think the preserving habit skipped a generation. My grandmother made jams and marmalade, and I do, but my mother didn't. Although she was a trained domestic science teacher, anything instant or ready-made she welcomed with open arms: instant puddings, Yeoman powdered mashed potato, Surprise dried peas, packet sauces, Vesta ready meals…

Rosalind, born 1955, urban

The family did not acquire a fridge or freezer until I was twelve. The house, a bungalow built in 1958, had a larder. There was also a 'butter cooler' – this was a terracotta dish (very breakable) surrounding a glass dish. The butter in the glass dish sat in a cold-water bath in the terracotta dish. Food was also sometimes left outside in the shade. Milk and bread were delivered daily and shopping was an almost daily activity. There was a major flurry of jam- and chutney-making in the autumn.

Derek, born 1956, rural

We did have a fridge when I was a little kid. We got a chest freezer when I was about twelve, I guess. We had moved into a new house built in 1962 and it didn't have a larder. Before the freezer we used to store stewed fruit in Kilner jars (glass jars with a rubber seal and a heavy-duty wire mechanism for fastening the lid down).

In 1960 we had a holiday in Cornwall in a flat that had no fridge so we stood the milk bottles in a bucket half-full of cold water with a cloth draped over them into the water. The evaporation of water from the cloth helped to keep the milk cool.

At home we used to have milk delivered every day except Sunday in pint bottles with silver tops – none of your semi-skimmed in those days – there was cream

on the top of it – and it was more creamy in the spring when the cows were put out to grass! The baker drove around in a little van and called twice a week.

Once a week, Mother would make a list of groceries, telephone the grocer in town and read out the list over the phone. Then the groceries would be delivered in cardboard boxes by the grocer's van.

We would also walk into town at least once a week to go shopping, about 3/4 mile, with mother pushing my little sister in the big old pram. This was a small town called Wareham, in Dorset, population in those days about 5,000.

Fruit and veg were certainly seasonal. I used to enjoy shelling the peas, which always came in pods.

Occasionally a French onion-seller would come around with strings of onions dangling from his bicycle. Mother would bargain over the price and then hang them up in the garage and they would last us for weeks.

We used to go and stay at my grandparents in Finchley, North London, where I used to like seeing the milk float being drawn by a horse and also selling orange juice in milk bottles.

Angela, born 1957, rural

We had a fridge when young and also a 'deep freeze' with a top opening. The house, built in the 1950s, had a larder.

Chris, born 1961, urban

Until I was about six we did not have a fridge but used a larder: a room with an outside small window and large stone shelf (the house was built in the 1930s). The freezer was a notable purchase (around 1970?). Milk was delivered daily – my parents recall this by horse-drawn cart before World War Two. There was a daily shop for food, especially for fresh bread. I don't remember any efforts being made to bottle, pickle or salt seasonal produce.

Helen, born ?, Rhodesia

Had a fridge and freezer when little – the climate was very hot. The house, built in 1951, also had a pantry. Milk was delivered daily and shopping trips were made on a weekly basis.

Kate, born 1966, rural

We had a fridge when little but no freezer – just the ice tray at the top of the fridge. The house, which was Victorian or Edwardian, had a larder, as were all the subsequent 1930s houses we moved into. These were all quite large houses built as rectories. Shopping trips were made weekly, there was a daily milk delivery and also a bread man I think. We stored apples and my mother made jams, pickles, etc.

Diana, born rural / surburban UK

Her family bought a fridge when she was seven or eight. The freezer came much later, in the early 1960s.

The house had been built in the 1920s or '30s and had a big larder with a slate shelf. When Diana was very small she had lived in a much older house which also had a pantry, and a huge walk-in cupboard for storing dried/tinned foods. '*Meat safes were a part of my childhood memories too, as were terracotta milk covers to keep the stuff cool. One meat safe was open to the outside on one side only, another actually*

fixed to the exterior wall. In the war years and for the duration of rationing, I remember fresh eggs being stored in a big vat of isinglass.'

Milk was always delivered as was cream and orange juice. Other foods retailers also delivered – the butcher, baker, grocer, greengrocer – the goods were often brought round by a boy on a bicycle with a basket.

Fruit was bottled or made into jam. Chutneys were also made. Eggs, onions, walnuts, beetroot, etc., were pickled. Her family did not salt any foods but knew people who did.

Female, born circa 1960, urban

Yes, had a fridge when I was about six or seven – mid 1960s. We didn't have a standing freezer. I can remember having a pantry in the house - the house was built in the early 1930s. We had milk delivered daily, and the fruit and veg man called once a week. I can remember my dad pickling his own onions and cabbage and making bramble jelly.

Alison, born 1967, rural

I had a fridge and a freezer when I was young. We also had a larder and various outhouses including one with a meat safe in it. The house was built post-1945

Milk was delivered every day, and we made a weekly trip to the local supermarket, which was five miles away. We bought vegetables from the farms nearby.

My mum worked on a farm for a while and whenever there was surplus food (i.e. the bits around the edges of fields that the machines missed, or peas that Birds Eye rejected) the workers were allowed to take stuff home. We would have mammoth sessions bagging and blanching food. I remember baths full of peas that my stepsister and I would have to pick the rubbish bits out of and hessian sacks full of sweetcorn that had also been rejected by the farm. Most of it was frozen – we had a massive chest freezer. Also, we made jams in the summer and pickles when there was a glut of vegetables.