

Electricity Use in the Commercial Kitchen

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Academic and industrial literature concerning the energy consumption of commercial kitchens is scarce. Electricity consumption data were collected from distribution board current transformers in a sample of fourteen UK public house-restaurants. This was set up to identify patterns of appliance use as well as to assess the total energy consumption of these establishments. The electricity consumption in the selected commercial kitchens was significantly higher than current literature estimates. On average, 63% of the premises electricity consumption was attributed to the catering activity. Key appliances that contributed to the samples average electricity consumption were identified as refrigeration (70 kWh, 41%), bain maries (27 kWh, 9%) and grills (37 kWh, 12%). Behavioral factors and poor maintenance were identified as major contributors to excessive electricity usage with potential savings of 70% and 45% respectively. Initiatives are required to influence operator behavior, such as the expansion of mandatory energy labeling, improved feedback information and the use of behavior change campaigns.

Keywords:

Electricity Use, Commercial Kitchen, Public House, Energy Conservation

1. INTRODUCTION

Commercial kitchens are some of the most profligate users of gas, water and electricity in the UK. As a result, they can leave a large carbon footprint, often using ten times the energy of the average commercial building (CIBSE 2012; S. Mudie *et al.* 2013). Catering businesses feature in virtually every town and city on a global scale and are vital buildings to be considered in any low carbon town. The UK is committed to an 80% reduction in greenhouse gas emissions by 2050, compared with 1990 levels (HM Government Department for Energy and Climate Change (UK) 2011).

The UK Carbon Trust and the Chartered Institute for Building Services (CIBSE) estimate that the total energy consumption of Britain's catering industry is in excess of 21,600 million kWh per year. CIBSE and the UK Carbon Trust estimate that 50% of this consumption originates from non-commercial catering businesses (hospitals, ministry of defence, schools etc.), with between 30-50% originating from activities of commercial kitchens (restaurants, public houses, cafes etc.) (Carbon Trust 2008; CIBSE 2009). However, these estimations are based on consumption in the USA. Despite their excessive usage, very little industrial or academic research exists pertaining to their current consumption, and energy reduction strategies (Carbon Trust 2011). There has been substantial research relating to energy use and reduction in the building fabric and envelope which may be applied to these premises. However, beyond the procurement of more energy efficient cooking appliances, very little innovation has been achieved. Indeed, the designs of cooking technologies have remained virtually stagnant since their creation (Newborough 1987).

Hot and cold meals are being prepared increasingly in public houses due to the increasing number of “*off licenses*” and shops selling alcohol and the tax levied on alcohol sales (Newborough and Probert 1988; Probert 1996; The Independent 2010). This has resulted in very few practical differences in the operation, licensing and management between restaurants and public houses (“pubs”) in the UK, giving rise to the colloquial phrase “gastro-pub”.

In order to fill the vast gap in the lack of published knowledge concerning commercial kitchens, the objectives of this study are to provide a comprehensive analysis of the electricity use in commercial catering establishments with a specific focus on the food preparation. The reduction of energy use from food preparation and cooking is seen as the largest challenge for these businesses if they are to continue to reduce consumption.

Consumption patterns of key appliances are explored and preliminary energy reduction strategies are suggested.

2. MATERIALS AND METHODS

2.1 Description of the Sample

Fourteen sites in England were selected to take part in this study. The relatively small sample size reflects the practical and financial constraints of extensive monitoring of such appliances; the type of intensive analysis makes it difficult to target a large sample size (Silverman 2011) e.g. 400 individual appliances were monitored in this study.

Each site belongs to a large chain of UK gastro-pubs which comprises 191 premises, all offering the same food menu. The fourteen sites were selected due to their “typical” range of appliances. Typical food items cooked include burgers, pies, sausages, hot sandwiches and casseroles. The equipment contained within the study kitchens is surprisingly varied given that they are part of a large chain. While there is a general template set-up for the pubs, the layouts, makes, models and capacities and volumes of the appliances differ greatly.

2.2 Monitoring of Electricity Consumption

Electricity supply was monitored using a system produced by a company - NoWatt Limited. The system consists of many purpose-built transformers which were fitted to breakers in the distribution boards of the incoming electricity supplies (Figure 1). Included in this were sensors. The sensors take sub-cycle readings at a rate of 12,800 times a second, enabling the differentiation of devices on a single circuit breaker by an advanced disaggregating software.

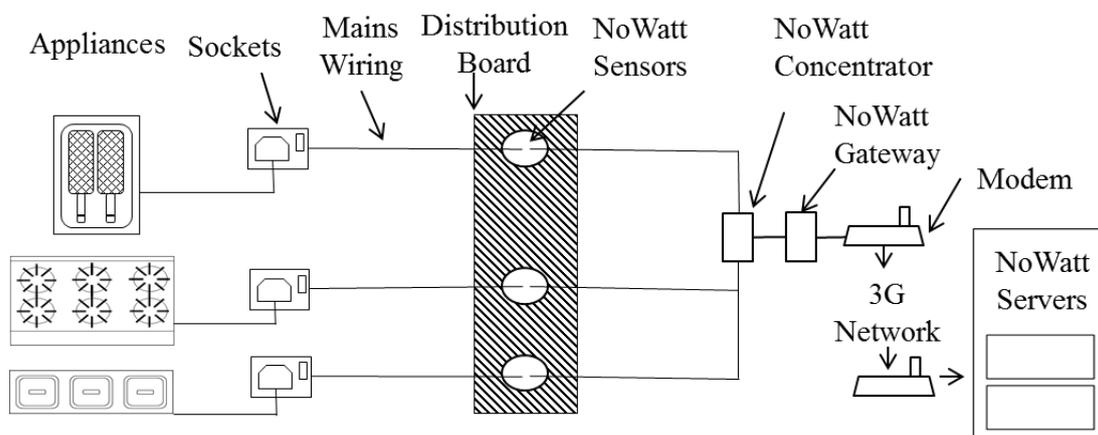


Figure 1 Diagram of appliance monitoring system

The sensors are connected to concentrators which send the high resolution readings (in real-time) to a signal gateway which then transmits the information to a central database via a Global System for Mobile Communications (GSM) network (3G). The raw data is stored in a standard SQL database (MySQL). There is no local display (or other features) on the sensors/concentrator; all information is retrieved from the central database (over the Internet). The advantages of such a system are that no additional wiring is required to commence monitoring, the system is relatively visually and practically unobtrusive and the data can be accessed in real-time in virtually unlimited resolution.

To ensure that this study was not subject to the Hawthorne effect (i.e. people who are aware they are being observed tend to alter their behavior (Wood and Newborough 2003)) kitchen operating staff were not informed of the monitoring.

2.3 Data Analysis

Whole building electricity and gas consumption was monitored for one year at one site to represent a case study of the gastro-pubs annual energy usage. This takes account of seasonal patterns of appliance use (such as heating and air conditioning) and consumer behavior (such as increased “eating out” in the holiday seasons). This information is analyzed by business-area and then by appliance end-use as described in Tables 1 and 2.

Table 1 Summary of Business (Physical) Area

Area	Description
Kitchen	Air handling, kitchen lighting, cooking equipment, refrigeration, hot storage, warewashing.
Restaurant	Air handling, restaurant, lighting, central heating, sundry sockets (vacuum etc.)
Cellar	Cellar cooling, beverage cooling, beverage pumps.
Bar	Glass washing, bar lighting, bottle fridges, ice machine, coffee machine.

Table 2 Summary of End Functions

Area	Description
Warewashing	Dish and glass washers.
Freezers and Fridges	All walk-in, stand alone and under counter refrigeration and freezing units, ice machines and cellar beverage chillers.
Cooking	All appliances utilized to prepare meals and store hot food, coffee machine.
Lighting	All external and internal lighting.
Air Handling	All air handling including ventilation, central heating, air conditioning and cellar cooling.
Other	Sundry sockets used ad-hoc (vacuum etc.), building alarms, hand driers, beverage pump, and office computer.

In all subsequent analysis, electricity use data has been gathered exclusively from all cooking and food storage appliances, omitting any kitchen ventilation, warewashing or gas consuming appliances. In these kitchens, gas is only consumed by a large chargrill (charbroiler) and a gas fired oven, usually with 6 hobs/burners.

For daily analysis of the kitchens' electricity expenditure, consumption was studied in the fourteen monitored kitchens over the period of one week (November 10th to November 16th 2012) as this represents the consumer cycle (more meals were served on Saturdays and Sundays). This is then averaged to form average daily consumption. It must be recognized that data pertaining to the week of study may be subject to seasonal and occupancy variations e.g. school holidays, unusual weather events etc. However, measurements were taken within experimental error to limit these effects. The period of study represents a "typical" weekly consumer cycle that does not fall during a holiday season.

To identify patterns of catering appliance usage, consumption was attributed to broad categories of an appliance e.g. "Fridge" or "Fryer". Even within the same chain of businesses, the kitchens contain different volumes, makes and models of appliances each with varying capacities, conditions and locations within the kitchens. It is particularly challenging to compare "like for like" appliances. Additionally, the kitchens vary in the volume of meals cooked. Therefore the consumption of each kitchen has been taken and averaged per day to indicate the average usage which should be treated with caution.

Data for each site and appliance were analyzed with Excel spreadsheets, to calculate the key values of consumption.

3. RESULTS

3.1 Whole Building Energy Use

Figures 2 and 3 display the annual profile of energy consumption for the case study site (including gas). The results should be considered within caution due to the singular sample case-study. Considering the business areas, Figure 2 clearly demonstrates that the kitchen is by far the largest consumer of energy. In terms of end function, energy consumed in the cooking of food, followed by the storage of food represent the largest expenses; almost 75% of the buildings annual consumption (Figure 3).

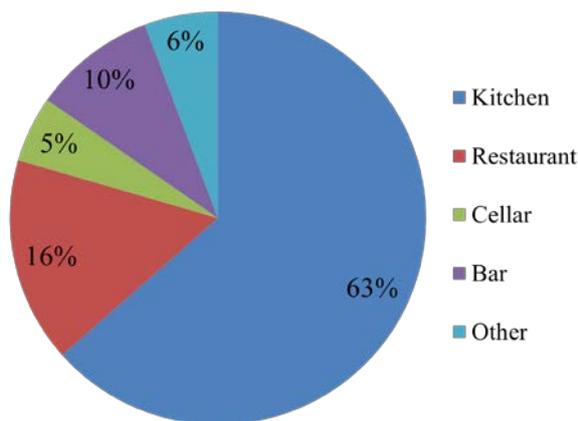


Figure 2 Monitored Energy Consumption by Business (Physical) Area

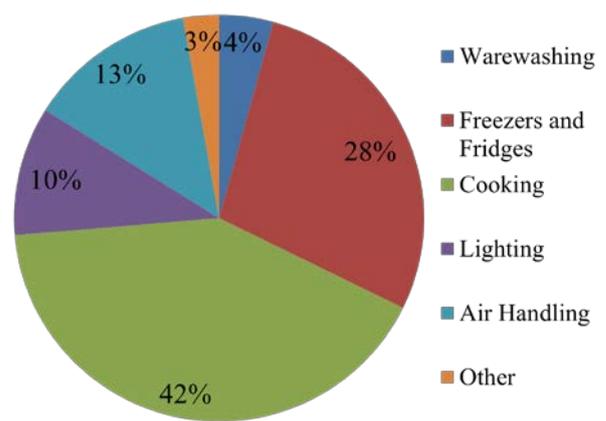


Figure 3 Monitored Energy Consumption by End Function

Annual consumption figures by area and function differ significantly from the previous estimates in published literature (23% and 6% used for cooking and refrigerated food storage respectively) (Carbon Trust 2008; CIBSE 2009). The consumption in the case study site represented a total expenditure of £37,872 (582,694 kWh); the second largest expenditure to the business after labor costs.

3.2 Kitchen Electricity Consumption

The average daily electricity consumption for the 14 kitchens is illustrated in Figure 4 together with the average number of meals served. This clearly demonstrates that consumption is only marginally affected by trade volume. As expected, there is increased consumption over the weekend. However, given a 152% reduction in meal output on a Monday compared with a Saturday (Figure 4), consumption only decreases by 20%. This is largely due to operator behaviour. Between the sites, there was significant variation in the kWh per meal “efficiency ratio”; 1.52 kWh/meal per week efficiency at Kitchen 3 (the most efficient kitchen), compared with 3.32 kWh/meal per week at Kitchen 7, the least efficient kitchen.

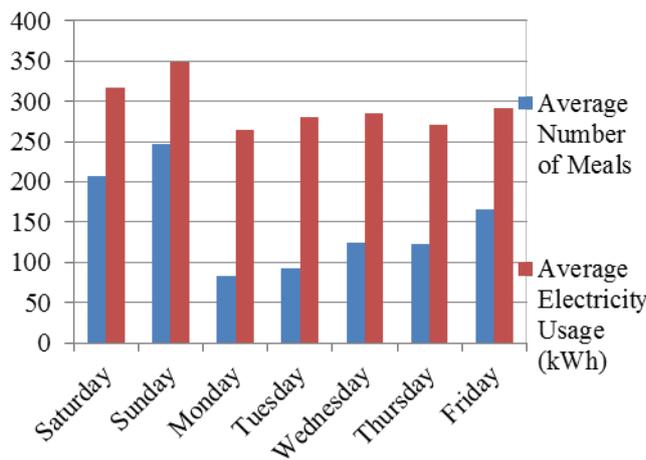


Figure 4 Kitchen Monitored Electricity Consumption (kWh) and Number of Meals Served

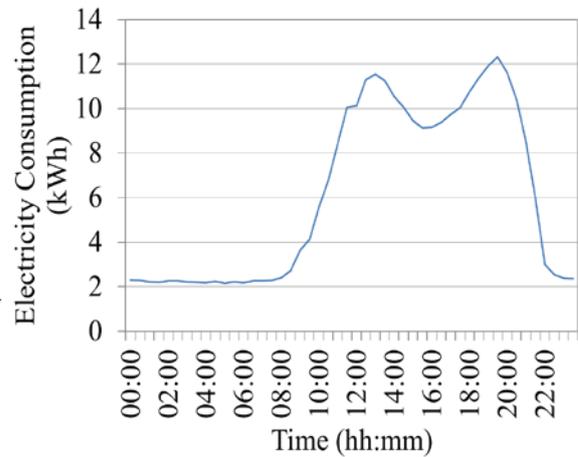


Figure 5 Kitchen Average Monitored 24 hour Electricity Consumption

The 24 hour profile of kitchen electricity usage has been averaged across all days of measurement and all kitchens (Figure 5). This demonstrates that the kitchens rarely reduce the consumption of appliances during the mid-afternoon lull in cooking volume, but should be interpreted with caution due to the small sample size and for the reasons discussed previously. The average daily usage for the sites was 294.4 kWh. Figure 5 also indicates that base load consumption (between 00:00-05:00) is 9% of the total load; the majority of this is refrigeration.

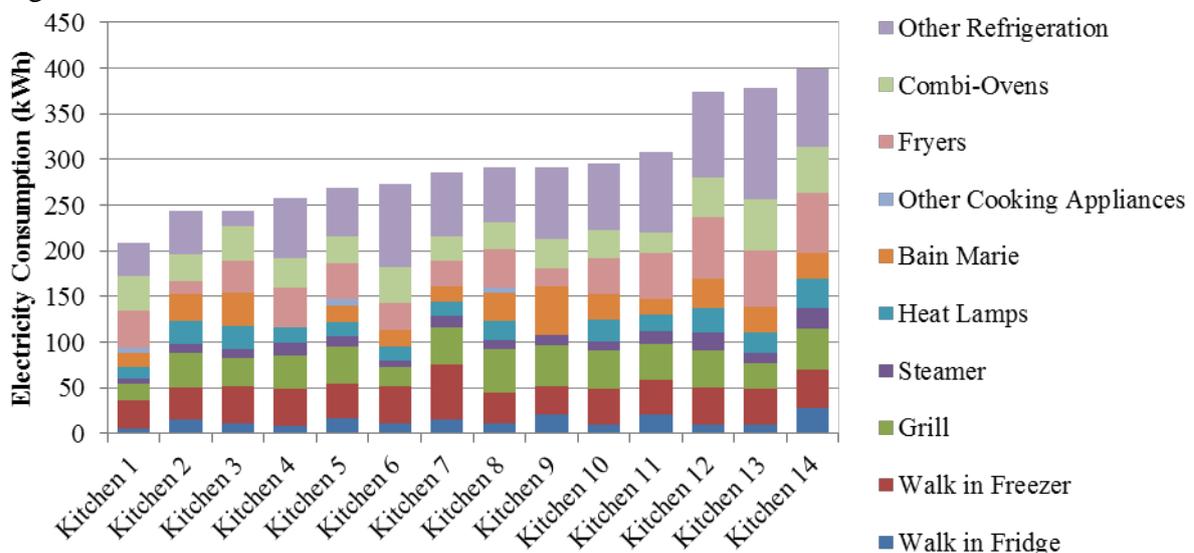


Figure 6 Average Monitored Kitchen Consumption Composition (kWh)

Figure 6 and 7 allocate the kitchens' electricity consumption into the main broad appliance categories. The variation in appliance electricity consumption between kitchens can be viewed in more detail in Figure 6 and Table 3. Figure 7 averages the data across all days of measurement and all kitchens. The total average refrigerated storage consumption is approximately 41%, with the remaining 59% attributed to cooking appliances.

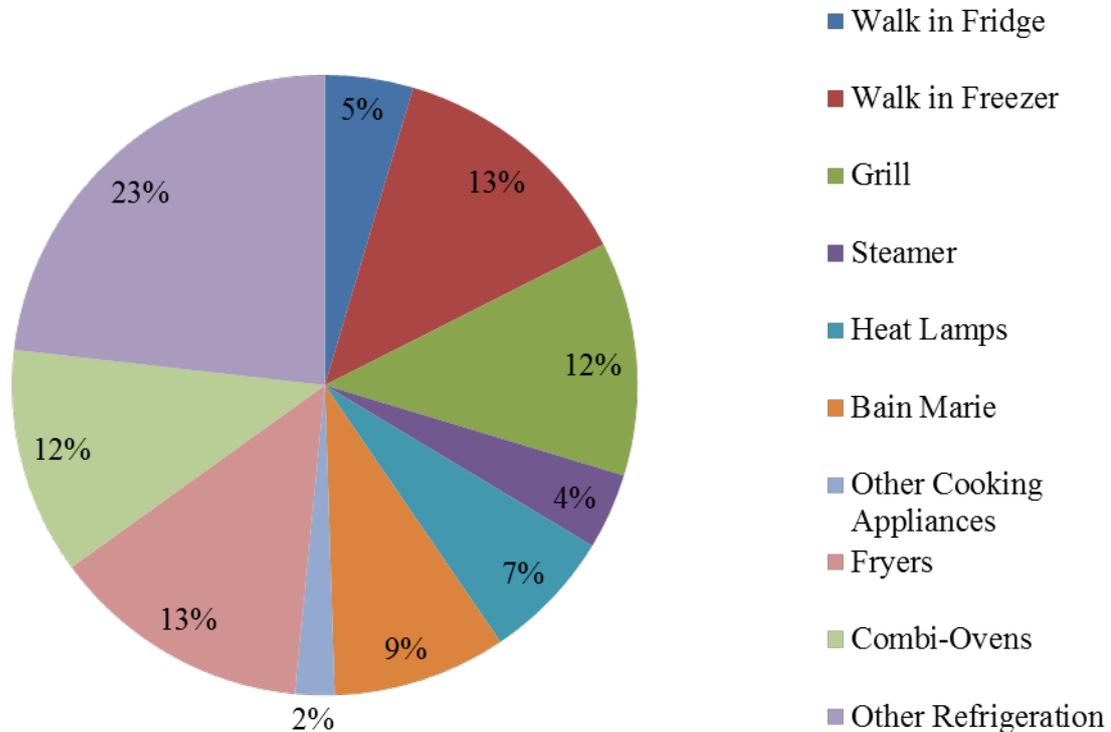


Figure 7 Average Monitored Kitchen Consumption Composition (%)

Table 3 Relevant Statistics of the Average Kitchen

Appliance Category	Ave. total daily (kWh)	Relative Standard Deviation (%)	Ave. Daily Carbon (kg CO ₂)	Ave. Daily Cost (£)
Walk in Fridge	13.81	45.89	7.14	1.52
Walk in Freezer	39.17	23.25	20.25	4.31
Grill	36.89	27.89	19.07	4.06
Steamer	11.99	47.35	6.20	1.32
Heat Lamps	20.70	35.42	10.70	2.28
Bain Marie	27.19	44.49	14.06	2.99
Other cooking appliances	6.08	37.35	3.14	0.67
Fryers	40.82	43.54	21.11	4.49
Combi-Ovens	35.71	34.16	18.46	3.93
Other Refrigeration	70.13	38.86	36.26	7.71
Total kitchen consumption	294.37	22.99	152.19	32.38

3.3 Key Appliances

3.3.1 Refrigeration

Refrigeration represents the largest consumption in each of the study kitchens. In addition to one large walk-in fridge and walk-in freezer unit at each site, the average number of additional refrigerating appliances was 9 units; 6 fridges and 3 freezers per site.

Overall, the conditions of the refrigerating appliances were poor. Ad-hoc observations indicated that approximately 50% of the units (including walk-ins) had some kind of fault or developing problem.

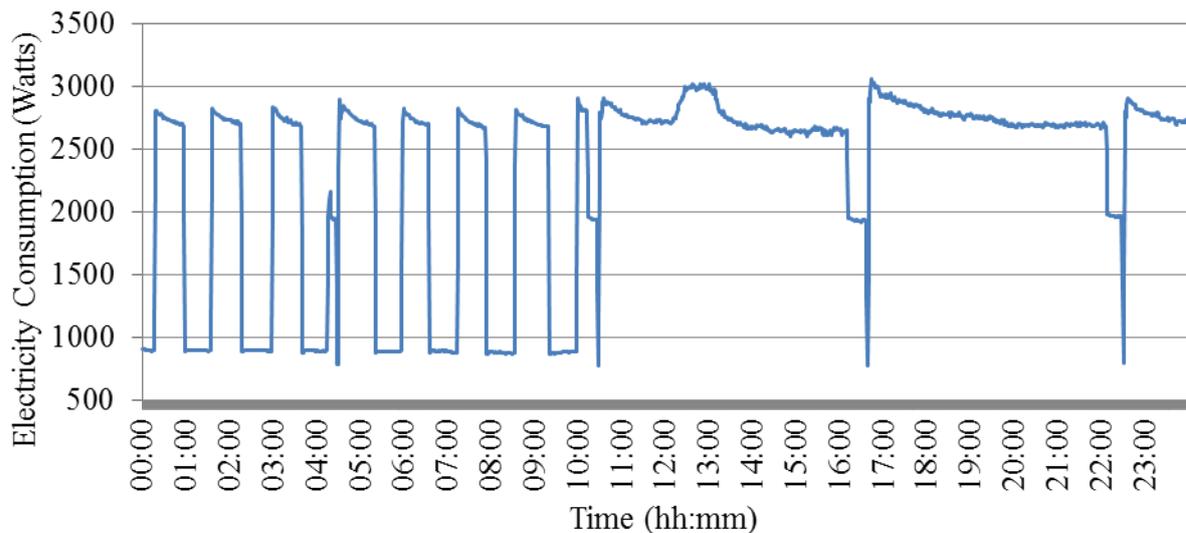


Figure 8 Walk-in Freezer Monitored Electricity Consumption (Watts) at Kitchen 12 on 10th November (pre-maintenance)

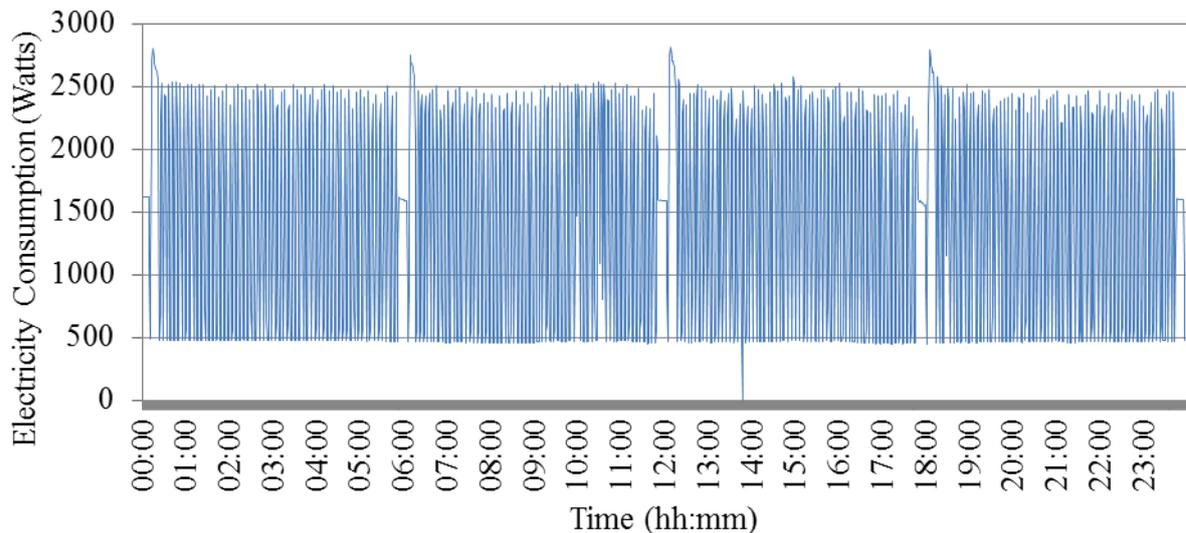


Figure 9 Walk-in Freezer Monitored Electricity Consumption (Watts) at Kitchen 12 on 16th November (post-maintenance)

While all other appliances in the study group remained in their respective states of repair throughout the monitoring period, maintenance was conducted on the Walk-in Freezer at Kitchen 12 during the week of study. Comparing the pre-maintenance daily consumption (Figure 8) with the post-maintenance usage (Figure 9), this represented a 45% electricity

reduction. A common fault observed was that over 50% of units displayed incorrect temperatures; the digitally displayed temperature is not always the actual monitored temperature of the refrigerator and this will correspond to electricity wastage (and has implications for food safety). Appropriate maintenance is vital to energy reduction in these premises.

The layouts of the kitchens did not lend themselves to energy conservation. Refrigerating appliances in close proximity to a heat source, (grill, etc.) were observed to have raised consumptions by approximately 30% in some instances. However the causality of this relationship cannot be determined in this study due to the highly variable makes, models, ages and conditions of the appliances.

An increased frequency of deliveries, lowering food storage capacity requirements is a consideration for energy reduction.

3.3.2 Grills

Grills contribute a relatively constant load to the kitchens electricity use (12%). The grill is significantly influenced by operator behavior. Figure 10 compares two grills of the same make and model on the same day. The grill in Kitchen 10 suffers from poor, (but typical) operator behavior. The appliance is switched to maximum where it remained until the end of service; it consumed 49 kWh. The grill in Kitchen 6 was managed much more appropriately from an energy conservation perspective; the temperature was reduced when not in operation. This grill consumed 14 kWh; 71% saving due to appropriate behavioral management alone.

It was observed during study that the grill was often used merely to brown items (such as sausages or cheese toppings) after oven cooking, which lasted only a few minutes. Options for reducing energy use include extending the oven-cooking time to include browning. The warm-up time of approximately 20 minutes may be an obstacle to turning it down/off.

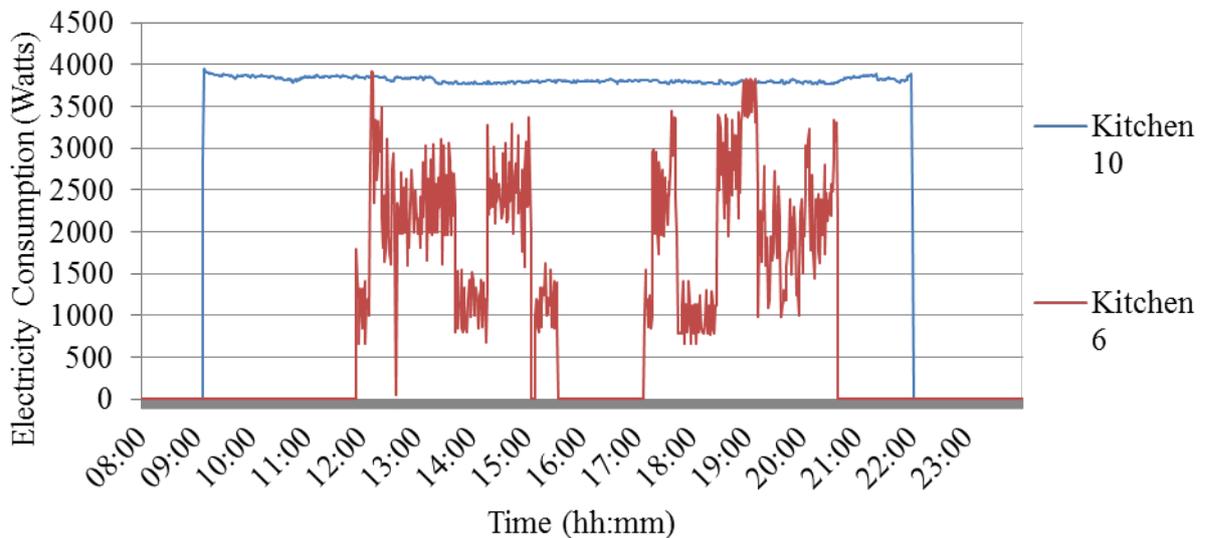


Figure 10 Grill Monitored Electricity Consumption (Watts) at Kitchens 10 and 6

3.3.3 Further Appliance Observations

The vast majority of appliances monitored had the option to be thermostatically controlled with varying levels of heat set by the operator, but this was poorly utilised. Only the consumption profiles of microwaves and to some extent fryers and combination ovens were found to relate to usage/food output; consumption increased during cooking and

automatically decreases after the pre-programmed cooking times. The appliances are not usually insulated; manufacturers claim this is due to associated fire risk (FSTC 2002).

Bain Maries are regularly employed in commercial kitchens to maintain food at the desired temperature while further food items are waiting to be served. Interestingly, research suggests that this practice reduces the nutrient content and palatability of the items (Probert and Newborough 1985). In the sample kitchens, Bain Maries were only used to keep sauces at serving temperatures and were correspondingly oversized for this function. Sometimes plates were held at high temperature within the cabinet. Hot-holding appeared to be an extremely wasteful and potentially unnecessary activity; with better management of the cooking operations elimination of hot-holding may save an average of 48 kWh per day.

4. CONCLUSIONS

Electricity consumption is vastly greater than literature estimates suggest with the kitchen and food related activities greatly outweighing other energy consuming activities. Consumption is highly variable between kitchens and appliances.

Catering appliance design does not lend itself to energy-thrift behavior. One clear approach to energy reduction is through better product design; this has been the focus of recent UK and EU policy via the Eco-design of Energy using Products Directive (2005/32/EC), which was recast and enlarged to include catering appliance in 2011 (Eco-design of Energy-related Products Directive – 2009/125/EC).

Operator behavior is a major factor in the excessive use of electricity. A strict “turn-on, turn-down, turn-off” schedule could be provided, however it is likely that in the busy working environment this may be ignored given that controls are available but not used by the operator. Turning appliances down/off when not required would save significant amounts of energy, carbon and cost. More research is required in order to motivate staff in this area.

Poor levels of maintenance significantly contribute to excessive energy use in refrigerators. Generally, correct sizing and consolidation of refrigerated storage will also see energy reduction benefits, this could include more frequent deliveries.

There is much potential from further research into the choice of cooking method and corresponding appliances. Many different methods of cooking the same item were observed during this study. Better management of these choices should focus on reducing the need for hot-holding.

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REFERENCES

- Carbon Trust (2008). Food preparation and catering - Increase carbon savings without compromising on quality - CTV035. 6th Floor, 5 New Street Square, London EC4A 3BF.
- Carbon Trust (2011). Industrial Energy Efficiency Accelerator – Overview on the catering sector - CTG060. 6th Floor, 5 New Street Square, London EC4A 3BF.
- CIBSE (2009). TM50 - Energy Efficiency in Commercial Kitchens. The Chartered Institution of Building Services Engineers (CIBSE) and Catering for a Sustainable Future Group (CSFG). CIBSE, 222 Balham High Road, London SW12 9BS
- CIBSE (2012). Guide F Energy Efficiency in Buildings. The Chartered Institution of Building Services Engineers (CIBSE) 222 Balham High Road, London SW12 9BS.
- FSTC (2002). Commercial Cooking Appliance Technology Assessment. Food Service Technology Center (FSTC) Report #5011.02.26. Fisher-Nickle, inc. 12949 Alcosta Boulevard, Suite 101, San Ramon, CA 94583.
- HM Government Department for Energy and Climate Change (UK) (2011). The Carbon Plan: Delivering our low carbon future, HM Government (UK), Department for Energy and Climate Change.
- McCrave, C. and Probert, S.D. (1996). "Some Economically Viable Techniques for the Reduction of Energy Expenditure in British Public Houses." *Applied Energy* vol. 54 Issue 1: 67-73.
- Mudie, S., Essah, E.A., Grandison, A., and Felgate, R. (2013). Benchmarking Energy Use in Licensed Restaurants and Pubs. Chartered Institute of Building Service Engineering (CIBSE) Technical Symposium 2013, Liverpool John Moores University, UK
- Newborough, M. (1987). Energy-Efficient Cooking Systems, Food-Preparation Facilities, And Human Diets. PhD thesis, Cranfield Institute of Technology.
- Newborough, M and Probert, S. D. (1988). "Energy-Thrift Opportunities for Operators of 'Public Houses' in the UK." *Applied Energy* vol. 31: 31-57.
- Probert, S. and Newborough, M. (1985). "Designs, Thermal Performances and Other Factors Concerning Cooking Equipment and Associated Facilities." *Applied Energy* vol. 21: 81-222.
- Silverman, D. (2011). *Interpreting Qualitative Data: A Guide to the Principles of Qualitative Research*. London: Sage Publications.
- The Independent (2010). Struggling Pubs Target the Restaurant Trade. The Independent - Martin Hickman. Available at: <http://www.independent.co.uk/news/business/analysis-and-features/struggling-pubs-target-the-restaurant-trade-2052365.html>. Accessed 11th April 2013.
- Wood, G. and Newborough, M. (2003). "Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design." *Energy and Buildings* vol. 35: 821-841.