Supplementary Material (Online Resource)

Improving Energy Efficiency in Manufacturing using Peer Benchmarking to Influence Machine Design Innovation

*Clean Technologies and Environmental Policy*

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1. Evidence for lack of energy monitoring at machine and process level by UK food manufacturers

The Introduction to this paper says that “a [state of the art] review found a clear lack of data on energy consumption in the sector at process, machine and machine component levels.” It also says that the review also “concluded that few food manufacturers in the UK acquire data to process/machine level, and of those which do, there is only partial coverage of their operations. Most companies only have data from their site utility meters, enabling them to produce an overall Specific Energy Consumption (SEC) figure (e.g. kWh/kg of output) but nothing more granular to provide greater intelligence on sub-optimal energy use. The main reasons for the lack of engagement at this level appear to include the costs of hardware, installation and associated software and analysis, whether using internal or external expertise, as well as lack of awareness and priority.”

The Supplementary Information (SI) given here provides the evidence base for these statements. Bear in mind that this is evidence for a negative conclusion i.e. an absence of data, so is inherently more difficult to gather than evidence for something which exists or is true.

a. Survey

We wanted to carry out a survey of food manufacturers to ask about their use of energy sub-meters. Literature searches had established that no such survey data existed. The UK’s Food & Drink Federation did not want to support such a survey.

We concluded that a survey would be of limited value, and perhaps misleading, because there was a significant possibility that a majority of the self-selecting responders would be companies which were using sub-meters to a greater or lesser extent. This would risk a non-representative ‘false positive’ response profile. We did not have funds to counter this effect by paying a random selection of companies to respond.

b. Energy Savings Opportunity Scheme (ESOS)

At the facility level (process and product), the introduction of the EU Energy Efficiency Directive (2012/27/EU) in 2012 is an indication that most EU F&D manufacturers did not at that time have processes in place for measuring their energy consumption, particularly at the level of detail needed to profile their consumption by process and product. Our analysis in 2017 of the first set of data returns under the Directive in the UK indicated that this was still the case in the UK.

The UK implemented the Directive through the Energy Savings Opportunity Scheme (ESOS) Regulations in 2014. ESOS aims to stimulate and accelerate improvements in industrial energy efficiency by forcing the generation, collation and analysis of data on energy consumption by large companies and organisations, but only at the site level (utility meter). ESOS obligations include the compilation of an audit for an eligible industrial site or group of sites. Energy consumption profiles are required, to identify significant areas of consumption, but only in broad categories, such as ‘buildings’ or ‘building A’, ‘transportation’ or ‘compressed air’.

Uniquely, we analysed the limited publicly available information on ESOS returns[[1]](#footnote-1) from the 191 food manufacturers in the UK obligated under the ESOS Initial Compliance Period (2014-15). These were identified by selecting food manufacturers in the UK registered with Companies House by 3 February 2017 from the entire Companies House database, and then identifying from these the companies appearing in the ESOS returns, complete by the registration deadline of 30 June 2016. (The method for doing this is available in the Data associated with this paper.) Table S1 lists what the ESOS returns for UK food manufacturers show, together with possible actions associated with each conclusion:

|  |  |
| --- | --- |
| Conclusion | Possible Actions |
| * Very few companies use ISO 50001 (the energy management standard). | Driving the establishment of energy management systems would stimulate significant energy efficiency action, but it could not be imposed and so would involve significant effort. |
| * A significant proportion of companies (31%) do not have documented energy consumption records. | Data capture is an important action (see section 3.2). |
| * Nearly all companies profiled their energy consumption, but this may have been at a high level. | Detailed data capture would enable automated profiling via software. |
| * The data suggest that only a minority have targets or benchmarks (taking the 25% ‘no’ answers and 62% ‘no response’ answers together), including those companies who also have CCL/CCA targets, but that 54% of ‘no’ and 10% of ‘no’ + ‘no answer’ now intend to adopt them. | This supports the above actions. |
| * More manufacturers need to involve senior management in reviewing ESOS data and actions, adding to the 38% which said that senior management were involved. | Barriers to doing this need to be understood. CPD intervention for managers, perhaps via all relevant professional bodies (which in many cases will not be involved with energy, e.g. Chartered Institute of Management, Institute of Directors). |

Table OR1: Conclusions and Possible Actions from ESOS Data Analysis

The responses from which these conclusions are drawn are set out below.

Analysis of Some Energy Metrics for Food Manufacturers in England from the 2016 ESOS Return

*Some percentages do not add to 100% because of blanks for some respondents*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ESOS Question | None | % | All | % | Some | % |
|  | To what extent are the UK organisations/sites/energy supplies in this ESOS notification covered by ISO50001? | 180 | 94% | 8 | 4% | 3 | 2% |

Comment

Certification to ISO50001, the international energy management standard, which covers all the company’s assets and activities, counts as the ESOS assessment in place of providing an Audit Pack.[[2]](#footnote-2)

This can only be noted at this stage, because it cannot be used to draw firm conclusions about a manufacturer’s knowledge or management of their energy consumption. If it can be assumed from the data that those in the 94% segment do not operate any form of management system which covers energy, it can be said that it would be easier to improve energy efficiency in UK food manufacturing if many more companies were certified to ISO50001, or at least implemented it without formal certification. This is a policy implication for government and for food industry leaders and representatives.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ESOS Question | Yes | % | No | % |
|  | Did you have to estimate any of the data to calculate your total energy consumption or energy spend (i.e. you didn't have 12 months actual data for all supplies)? | 60 | 31% | 123 | 64% |

Comment

It is surprising that a third of companies had to estimate consumption or spend, since all inputs are invoiced which should provide quantities as well as cost for each purchase unit or period. All companies obligated under ESOS are classified either as ‘large’ by employment and/or turnover plus balance sheet values, or are part of a large company, or of a group with operations in the UK classified as ‘large’. All companies in our list should therefore have the resources to marshall meter readings and invoice data to avoid having to estimate.

For those which did not need to use estimates, a remaining unanswered question is the degree of detail they achieved in measuring their consumption.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ESOS Question | Yes | % | No | % |
|  | Did you use energy consumption profiling for the purpose of analysing your energy consumption for all your ESOS energy audit(s)? | 175 | 92% | 8 | 4% |

The high proportion of companies using profiles is not surprising since under the Regulations they would need to justify why they had not used profiling in their analysis.[[3]](#footnote-3)

Since a third of companies had to use some estimation of consumption (see previous question), the validity of their profiling may be relatively poor. The profiling for all companies may have been at a high level. These are reasons for direct measurement of consumption to an appropriate extent.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ESOS Question | Yes | % | No | % | No response | % |
|  | Voluntary question: Does your UK organisation have a quantitative energy efficiency target and/or benchmarks? | 47 | 25% | 26 | 14% | 118 | 62% |

Comment

In these results, we assume that lack of a response, even though an answer is not mandatory, indicates in the majority of cases that the company does not have targets or benchmarks. Some respondents may have skipped the whole section since it is marked as voluntary, but it seems more likely that a significant number would have quickly scanned the questions, and if they had targets, they would have wanted to let the relevant environment agency know.

The answers here correlate with the low proportion of companies whose ESOS notifications were covered by ISO50001; a key part of the Standard is the setting of targets. The results indicate a potential improvement action for the industry with regard to its approach to energy efficiency.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ESOS Question | Targets stated | % | No response | % |
|  | Voluntary Question: If your UK organisation does have a quantitative target and/or benchmarks can you disclose a key target or benchmark? | 37 | 19% | 154 | 81% |

Comment

The result here is in line with the previous question, so no additional comment.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ESOS Question | Yes | % |
|  | Voluntary question: If your organisation does not have a quantitative target and/or benchmarks will you adopt any such measures in light of your ESOS assessment? | 14 | 54% |

Comment

These 14 companies seem most likely to come from the 26 who answered ‘no’ to Q4. This suggests that improving energy efficiency in the food manufacturing sector going forward may be a challenge.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ESOS Question | Yes | % |
|  | Voluntary question: Have the board of directors of your organisation discussed the results of your ESOS assessment? | 57 | 30% |

|  |  |  |  |
| --- | --- | --- | --- |
|  | ESOS Question | Yes | % |
|  | Voluntary question: Have senior management within your organisation discussed the results of your ESOS assessment? | 72 | 38% |

Comment

If we can assume that most companies read this question, the proportion of positive responses to these questions is disappointing, but in line with the pattern of results from the voluntary questions and the previous comment.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ESOS Question | Yes | % | No | % |
|  | Voluntary question: Have you published any information relating to your ESOS energy audit report? | 3 | 2 | 65 | 34 |

Comment

This is surprising, because for Q5 37 companies disclosed a key target or benchmark, and many of those are likely to have achieved their target, which would be a positive story to tell the world, for example in a press notice. On the other hand, such information may be seen as commercially sensitive, on the basis that competitors should not be told of progress in reducing costs. If this is a reason for not publishing information, then it has implications for peer benchmarking and improvement competition discussed in the paper associated with this Supplementary Information.

Below is one of the few detailed returns which had permission to publish. It shows that the energy consumption profiling was not at machine level, and only broad areas of process which are commonly focused upon as areas of opportunity for energy efficiency improvements.

*Safe House Holding Ltd (t/a BM Foods Ltd & Winning Blend t/a the Welsh Pantry and Get Stocked)*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Project No: | Title | Cost Saving (£ Per Annum) | Cost to Implement (£) | kWh Saving (per annum) | CO2 Savings (T per annum) | Pay back (Years) | Site/Location Priority |
| 1 | Improved Gas/Electricity Monitoring | £47,290 | £8,731 | 538,439 | 171 | 0.2 | All High |
| 2 | Energy Awareness Training for Staff | £47,290 | - | 538,439 | 171 | Immediate | All High |
| 3 | Replacement of Low Temperature Hot Water Gas Boiler | £2,200 | £11,000 | 1,929 | 2 | 5 | BM Foods Medium |
| 4 | Reduce Temperature Range on Stocked Mobile Chillers | £99 | - | 991 | 0.5 | Immediate | Stocked Medium |
| 5 | Installation of Energy Efficient Lighting Throughout the Factory | £63,147 | £82,844 | 462,139 | 250 | 1.3 | Winning Blend High |
| 6 | Completion of Installation of LED Luminaires | £2,264 | £3,600 | 56609 | 24 | 1.6 | BM Foods High |
| 7 | Installation of LED Luminaires | £3,235 | £7,440 | 32,348 | 35 | 2.3 | Stocked High |
| 8 | Replacement of Electric with Gas Kettles | £13,104 | £132,000 | 43,680 | 69 | 10 years | Winning Blend High |
| 9 | Compressed Air Leakage Detection | £17,739 | Nil | 197,100 | 91 | Immediate | Winning Blend High |
| 10 | Compressed Air Leakage Detection | £4,040 | - | 40,404 | 19 | Immediate | BM Foods High |
| 11 | Energy Efficiency Driver Training | £19,044 | 5,400 | 19,044 | 3 | 0.3 | Stocked High |
| 12 | Improved Analysis and Targeting Using Vehicle | £30,471 | - | 30,471 | 4 | Immediate | Stocked High |
| TOTAL |  | £249,923 | £251,015 | 1,960,602 | 839.5 |  |  |

ESOS - Conclusion

Our analysis of the ESOS returns for the Initial Compliance Period yields no evidence that large UK food manufacturers are measuring the energy consumption of their machinery to any significant extent.

c. Interviews with energy managers at four large manufacturers (five sites)

Our conclusion was that, whilst these leading companies do have partial or extensive sub-metering, one acknowledged the cost challenge, and their partial use of various types of software or in one case Excel indicates that this was the state of the art and that smaller companies would be behind them.

A written record of these interviews exists but is not generally available as Research Data because they were given on the condition of anonymity. Were the names of people and company to be redacted, it seems to me that the companies’ identities could be deduced from the comments, but this is a judgement that Loughborough staff would need to make if there was a request for exceptional access.

Reading online articles in trade publications, particularly *Machine Design, Control Design* and *Food Manufacture*

A common impression from these was that energy data acquisition at machine level was not common and that cost was a barrier.

My experience of energy efficiency consultancy at one non-food advanced components manufacturer, and my career knowledge of the common barriers to investing in EE measures in manufacturing.

d. Review of hardware and software

My review of relevant hardware and software provided strong indications of limited sales at the machine level. This is detailed in my draft (unsubmitted) papers listed below (copies of which are in the Data Folder) and in the literature I read.

* Review Paper v5
* Literature & Activity Review v4
* EE in F&B Manufacturing – State of Knowledge Summary v4

*Phil Sheppard, October 2018 and March 2019*

2. Examples of GS1 codes for intermediate and final products

The GS1 system [1] enables unique classification of products. Tables OR1 and OR2 give a brief illustration of how an intermediate and a corresponding final product would be identified.

**Table OR2. GS1 Classification hierarchy for dough used for perishable bread**

|  |  |
| --- | --- |
| Segment Code | 50000000 |
| Segment Description | Food/Beverage/Tobacco |
| Family Code | 50180000 |
| Family Description | Bread/Bakery Products |
| Class Code | 50181700 |
| Class Description | Baking/Cooking Mixes/Supplies |
| Brick Code | 10000155 |
| Brick Description | Baking/Cooking Mixes (Frozen) |
| Core Attribute Type Code | 20000013 |
| Core Attribute Type Description | Type of Baking/Cooking Mix |
| Core Attribute Value Code | 30017171 |
| Core Attribute Value Description | BREAD DOUGH MIX |
| Core Attribute Type 1 Code | 20000056 |
| Core Attribute Type 1 Description | Diabetic Claim |
| Core Attribute Type 2 Code | 20000142 |
| Core Attribute Type 2 Description | If Organic |
| Core Attribute Type 3 Code | 20003041 |
| Core Attribute Type 3 Description | Method of Preparation |
| Core Attribute Type 4 Code | 20003042 |
| Core Attribute Type 4 Description | Requires Additional Ingredients |
| Core Attribute Type 5 Code | 20000175 |
| Core Attribute Type 5 Description | Suitability for Vegetarians/Vegans Claim |
| Core Attribute Type 6 Code | 20000013 |
| Core Attribute Type 6 Description | Type of Baking/Cooking Mix |

**Table OR3. GS1 Classification hierarchy for dough used for perishable (short-life) bread**

|  |  |
| --- | --- |
| Segment Code | 50000000 |
| Segment Description | Food/Beverage/Tobacco |
| Family Code | 50180000 |
| Family Description | Bread/Bakery Products |
| Class Code | 50181900 |
| Class Description | Bread |
| Brick Code | 10000164 |
| Brick Description | Bread (Perishable) |
| Core Attribute Type 1 Code | 20000079 |
| Core Attribute Type 1 Description | Gluten Free Claim |
| Core Attribute Type 2 Code | 20000098 |
| Core Attribute Type 2 Description | If Flavoured or Added Ingredient |
| Core Attribute Type 3 Code | 20000142 |
| Core Attribute Type 3 Description | If Organic |
| Core Attribute Type 4 Code | 20000108 |
| Core Attribute Type 4 Description | If Part Baked |
| Core Attribute Type 5 Code | 20002712 |
| Core Attribute Type 5 Description | If Sliced |
| Core Attribute Type 6 Code | 20000153 |
| Core Attribute Type 6 Description | Refrigeration Claim |
| Core Attribute Type 7 Code | 20000190 |
| Core Attribute Type 7 Description | Type of Bread |
| There are 44 sub-types classified, and users can add more for their purposes | |
| Core Attribute Type 8 Code | 20000191 |
| Core Attribute Type 8 Description | Type of Cereal/Grain |
| There are 26 types and combinations classified, and users can add more | |

3. Benefits to Food Manufacturers from Sharing Data / Allowing Data Sharing

Circumstance 1: Pre-participation

1. Knowing where I am on the scale of energy efficiency potential would enable more effective decision-making about energy-related investments.
2. Allowing collection and sharing of data is a cheap way to obtain our machine-level data, allowing us to see it for the first time.
3. I could generate intellectual property through machine design innovation informed by the comparative data.
4. Having more innovation activity in, and attention to, machine design would benefit the more important elements of competition such as production quality and supply chain competitiveness, because such innovation would probably include these aspects too.
5. The comparative data could support energy efficiency improvements among suppliers, reducing my cost pressures.
6. Having a community of providers supporting and stimulating innovation would increase our degree of futureproofing against adverse events, including government policies, relating to the cost, supply and environmental impact of energy. We would probably be less affected, and/or able to produce a response more quickly.
7. Product prices are not much affected by energy costs, therefore not a differentiator for consumers, therefore sharing of data has no real effect on sales.
8. Where energy efficiency can lower prices, brand loyalty may be of higher importance to our market.

Circumstance 2: Worse machine performance in the database rankings

“From the data received, or what I know or suspect already, I'm worse than others.”

1. I want to improve my position in the league table, so I need to contribute my data.
2. Strengths 1-6 above.

Circumstance 3: Better machine performance in the database rankings or investment in machine improvement following initial participation

1. “I could now drop out of the system because I already know I'm better than the others and I'd be giving away my new advantage. However, this may only apply for say a year then they may have leapfrogged me, so I would then be curious to go back in, which would give me intelligence about my next improvement.”
2. “Staying in would also give me a certain amount of intelligence about machine design without comparative data, because the fine resolution and the pattern of consumption would identify below spec performance. I could get this by paying for data acquisition and analysis by a consultant, but staying in would be cheaper and have the comparison benefits as well.”
3. “I could get further ahead by staying in to leverage the stakeholder community’s innovation capability, and this would increase the pressure on my worse-performing peers because they could now be preoccupied with machine energy efficiency improvement, so weakening their competition on other competitive issues.”
4. Machines at my other sites (not yet monitored) might not be among the best.
5. Strengths 4, 5, 6 & 7 under ‘Circumstance 1’ above.

Circumstance 4: Advanced food manufacturers, using leading edge technologies and machine designs

There are circumstances in which the Advanced group could lose, or incur an opportunity cost, by keeping their data. These are:

**Blocked access**: Where the terms for food manufacturers gaining access to the Database include a requirement to submit data, so that the Advanced manufacturers cannot see whether their assumption of leading status is correct.

**Business intelligence**: In the same scenario, they would not be able to quantify their advantage in energy or financial terms based on varying assumptions about the outputs of other manufacturers who have contributed data.

**Reduced future capital cost**: ‘Although I know that my investment in infrared ovens gives me the lowest possible energy consumption, if I help to increase demand through data sharing, the cost of my next investment in the technology is likely to be lower.’

3. Benefits to the Food Manufacturing Industry from the Proposed System

Companies freely share some competitively significant information already:

* Salaries of vacant posts and top salaries
* Manufacturing methods e.g. automotive factory tours, Toyota lean manufacturing methods
* Some patents e.g. Toyota fuel cells, Tesla
* Lifecycle analysis data, particularly in the leading GaBi package
* Energy Star Performance Index, Energy Intensity Index

Whilst capability gradients in a perfect economic model are good, because they distribute production burdens and exchange of rewards optimally, information gradients are characteristic of an imperfect, inefficient economic model.

Such economically inefficient industries mean that there is less consumer money available for all products in an industry. If the least energy-efficient manufacturers improved and this led to lower prices, consumer money would be freed for spending on more or higher quality products.

The comparative data could enable UK machine manufacturers to be more competitive, which could make procurement and servicing easier and cheaper for the UK food manufacturing industry.

The more intense and continuous focus on machine innovation should counteract the rebound effect, by preventing food manufacturers from shifting their focus to product and process innovation which would incur higher specific energy consumption, which would be possible due to the greater energy efficiency achieved from machine design innovation.

Reference

1. GS1 UK Ltd. GS1 General Product Classification [Internet].

1. Available from <https://data.gov.uk/dataset/energy-savings-opportunity-scheme>. [↑](#footnote-ref-1)
2. Environment Agency (2016). Complying with the Energy Saving Opportunities Scheme, Version 5.0. [↑](#footnote-ref-2)
3. Environment Agency (2016), *op cit.* [↑](#footnote-ref-3)