COMPARISON OF EATWARE SYSTEMS AT THE SHAMBALA FESTIVAL

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The Shambala Festival (SF) provides meals for ‘crew’ – the workers who prepare the site, deliver the festival services, and clean up afterwards. The whole process lasts 14 days, with three meals a day. In 2017 these meals were served on paper plates with wooden utensils (one hesitates to call them ‘cutlery’) which were then collected and incinerated, with a certain amount of energy recovery. In 2018 the meals were served with enamelled steel plates and stainless steel cutlery, washed and re-used. These plates and cutlery were then stored for use in future festivals.

SF have asked me to evaluate the relative greenhouse gas emissions (GHGE) from the two systems. At first sight it might seem obvious that a re-use system must have lower emissions than a single-use and throw-away system, but careful quantitative analysis often contradicts simple assumptions.

SF have supplied some basic information, and I have gained further information from the Environmental Health Officer (EHO) and members of the catering team. I have not been able to obtain any information regarding waste handling and energy recovery, or detailed workings of the dishwasher unit or the hot water boiler. Much of the data is in the form of ‘guesstimates’ from SF staff that have to be taken as given, and I have drawn also on generic information from the literature.

INFORMATION AVAILABLE

The information I have been given is as follows:

The total number of meals served was 9832, and it is estimated that 20% of these were ‘takeaways’ served in cardboard containers. We do not know how this figure was arrived at, but taking it at face value, the total number served on plates was 9832\*0.8 = 7866.

Over the period of the festival proper, more detailed statistics were obtained for numbers of meals:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fri 24 | 494 | 197 | 528 | 1219 |
| Sat 25 | 449 | 148 | 469 | 1066 |
| Sun 26 | 410 | 126 | 435 | 971 |
| Mon 27 | 166 | 243 | 363 | 772 |
| Tues 28 | 49 | 118 | 121 | 288 |
| Wed 29 | 34 | 40 | 36 | 110 |
|   |  |  |  | 4426 |

These are also subject to the 20% deduction for takeaways, so the actual number of plates used in this period was 3541.

Water-consumption was also metered over the festival days, as shown in the adjacent table. The total consumed in this period is 47.85 kL.[[1]](#footnote-1) Pro-rating for the total number of meals gives 106.3 kL for the whole festival.

Cold water feed temperature was assumed to be 18°C.

Use of propane gas for water-heating was reported as 41 kg, although I also received a report from catering staff that actually 94 kg were used. Electricity consumption of 280.4 kWh is reported, but it is not clear what this is for, and how much of the operation it covered.

A stock of 500 enamelled steel plates was obtained, each weighing 220 g. Stainless steel cutlery was also obtained, weighing 50 g apiece. I assume there are 500 each of knife fork and spoon. These all belong to SF and are intended for re-use over many years.

Paper plates used in 2017 weighed 15 g, while wooden utensils weighed 2 g.

WASHING EATWARE

The washing process was as follows. Users scraped large pieces of food into a container, then rinsed plates and crockery under a tap with warm water at around 35°C. The items were then placed in larger containers ready for processing in the dishwasher. The waste water was ‘run into a ditch’.

The dishwasher was an under-counter model similar to the Meiko Ecostar 530 F. The items are taken from the containers and stacked in the dishwasher tray. 12 plates can be processed in one cycle. They are sprayed with hot soapy water at 57°C for about 80 seconds from a tank with a capacity of about 8 L, with a final rinsing peak of 65°C for about 10 seconds, using fresh water at about 2 L per cycle. The warm plates are then removed and racked to air-dry. The whole stack-wash-unstack cycle takes around three minutes. The tank water was discharged and refilled three times a day, presumably after each meal. Waste water was collected and stored, then tankered away for treatment.

Detergents and ‘rinse-aid’ were also used in the dishwasher, 10 L of each through the festival, about 15 mL of each per cycle.

A sample temperature profile was taken by the EHO as follows. The rinse peak can be seen at the end. This is a fairly long cycle, but I understand the SF machine has a 90-second setting and this was used during the Festival, with sanitising results satisfactory to the EHO.



It is worth giving more details about the operation of such machines. This is a commercial machine designed to wash items much more quickly than a domestic machine. A tank of water is maintained at high temperature ready to start the next wash. It is not renewed at each cycle, but is filtered and re-used. When a new cycle begins, this water is sprayed with added detergent onto the items for cleaning, and essentially removes all food waste but leaves a thin film of soapy and slightly dirty water. This is rinsed off by a further spray of fresh water at a higher temperature. This fresh hot water displaces some of the tank water, diluting it somewhat and keeping the temperature up. Usually the tank water is drained at the end of the day and the filters are cleaned. In SF practice, this process appears to have taken place after every meal.

ANALYSIS OF 2018 PRACTICE

There are several elements

* + GHGE from directly measured energy consumption
	+ GHGE from energy consumption inferred from water consumption
	+ GHGE embodied in goods used

The simplest result is obtained from the reported propane use. If 41 kg were used and propane has a carbon intensity of 2.99 kgCO2e/kg, then emissions are 41\*2.99 = **122.6 kgCO2e**. It was claimed this gas was used exclusively to heat water for the pre-rinsing process.

Calculating emissions from the dishwashing machine is more difficult, as I can find no overall energy data for this or similar models. A report regarding a much larger machine with a throughput of 2500 plates/hour gives 23 kWh/hour. If the SF process has a three-minute cycle and 12 plates per rack, that is 480/hour, so 4.2 kWh/h, or with 20 cycles per hour, 0.22 kWh per cycle. The total number of cycles for the whole festival is 7866/12 = 656, which gives an estimated consumption of 144.2 kWh.

This calculation assumes a simple extrapolation from a large to a small model, and is not really satisfactory. Another approach is to calculate energy requirements from known temperatures and quantities of water. If the 8 L tank was filled three times a day for 14 days, and had to be heated to 57°C initially on each of 3\*14 = 42 occasions, that is 8\*3\*14 = 336 L. Assuming an immersion heater in the tank and essentially 100% efficiency, this amount of heating would take 15.3 kWh of electricity.

Assume that no further heating is required for the tank water, because extra heat is supplied each cycle by the rinse injection. If the rinse water is 2 L per cycle as reported, that is a total of 2\*656 = 1312 L heated through 65-18 = 47°C. This would take 71.9 kWh.

Add these two together and we get 87.2 kWh, a lot less than the extrapolated estimate, but probably more reliable. It is a small fraction of the total electricity consumption reported of 280.4 kWh. Carbon intensity of grid electricity is slightly problematic in that it varies a great deal and is declining on account of the phasing out of coal and increase renewable supply. 0.34 kgCO2e/kWh is probably reasonable for the festival period, so GHGE from dishwashing would be 87.2\*0.34

= **29.7 kgCO2e**.

Heating is not the only cause of indirect GHGE. Supply and treatment of water must also be considered. The dishwasher used 1648 L, and this was all stored and tankered off-site for treatment. This quantity is small, so we shall ignore the haulage aspect. Probably government reporting guidelines are good enough here. For water supply 0.34 kg/kL and for treatment 0.71 kg/kL. So this total is 1.648\*0.34 + 1.648\*0.71 = **1.73 kgCO2e**.

This very small item for water supply and cleaning for the dishwasher might suggest a similarly small value for the rinse water, especially as the rinse-water is not tankered off site and treated. But we do not know how much water was used for rinsing. We know the approximate total water consumption, and we know the amount used for the dishwasher. Perhaps an estimate can be made from the reported energy input of 41 kg propane, and therefore 566 kWh, although allowing for efficiency of a commercial boiler of 80%, perhaps 453 kWh into useful heating. The temperature of rinse water has been reported as ‘between 30°C and 40°C’. Let us assume 35°C, a rise of 35-18 = 17°C. This would be enough to raise 22.8 kL to 35°C. Supply of this quantity of water is 22.8 kL\*0.34 = **7.76 kgCO2e**.

Is this value credible? It amounts to 2.9 litres per washing-up session, which sounds quite adequate, even rather generous, and is plausible. On the other hand, a common rule of thumb in commercial catering is that ‘washing up’ takes about two-thirds of the water used, and we now have 24.53 kL in a total water usage of 106 kL, only 23%. Where has all this other water gone?

One possibility is that the gas consumption is not the ‘official’ 41 kg, but 94 kg as one of the catering staff reported. In this case 53.2 kL of water could have been heated and used for rinsing, 6.6 L per plate meal. This is more in line with catering statistics, but is it at all credible?

The rinsing sinks had taps that were meant to be turned on and off, and this was almost invariably observed by single users. However, when a queue formed, it was perhaps thought courteous to leave the tap running for the next user. By the time (say) the tenth user arrived, it might well have been assumed that ‘leave the tap running’ was the intended method of use. This could account for very high levels of consumption. If this was indeed the case, the GHGE from plate rinsing would rise from 123 to 281 kgCO2e.

EMBODIED CARBON

There are 500 plates at 220 g each, assumed to be standard mild steel. They belong to the festival and are expected to be re-used each year with a loss of 20% per year, giving a five-year cycle. Steel plate has a carbon intensity of 1.42 kg/kg so the initial embodied carbon is 156.2 kgCO2e, over five years gives 31.42 kg per festival.

Cutlery items are stainless steel, cited as 50 g apiece. It is not known how many sets there are, but it is observed that most diners use only two items per meal. Let us suppose the ordering of cutlery has followed this expectation. This gives us 500\*0.67\*3 = 1005 items, weighing 50.25 kg. At an intensity of 6.15 kg/kg this gives 309.0 kgCO2e initially. Loss rate is hard to estimate. Damage is negligible, but loss or theft will gradually reduce the total. Say ten-year cycle? Ignore credit from carbon saved by cutlery entering the ‘inventories’ of witting or unwitting ‘thieves’.

So average per festival 30.9 kgCO2e. But notice that if the total cutlery is actually 1500 pieces, this value goes up to 46.1 kgCO2e.

The carbon embodied in the dishwasher is hard to assess because we don’t know how many uses it has in its lifetime, what its recycled content is, or what will happen when it reaches the end of its useful life. But we ought to put something in. Say it weights 50 kg, of which half is stainless steel, half mild steel. This would give us about 200 kgCO2e. If it had fifty uses, this would allocate 4 kgCO2e to a single festival.

Soap/detergent is more serious. According to one study the embodied energy in washing liquid is 14 MJ/kg. Using our electricity value of 0.34, this gives 26 kgCO2e for the 20 L of detergent and rinse-aid used.

Total embodied per festival is then 31.4+30.9+4+26.0 = **94.3 kgCO2e**.

SO FOR 2018, THE TOTAL IS **256 kgCO2e**, or

**33 gCO2e PER MEAL** SERVED WITH PLATE AND CUTLERY.

But note that there are uncertainties here. The worst-case interpretation of the data would give total emissions of and 427.7 kgCO2e and **54 gCO2e per meal**.

ANALYSIS OF 2017 SYSTEM

For comparability, assume that the number of meals is the same, and the proportion of takeaways is the same, and both systems have the same cardboard containers for these.

Paper plates were 15 g apiece, and wood utensils 2 g. Assume the same number of meals, total weight of paper = 7866\*0.015 = 118.0 kg. With same assumptions for utensils (two items per meal) 31.5 kg, or for three items per meal 47.2 kg. Carbon intensity for paper in the literature is highly variable, but UK government guidelines give 0.84 for paper and board that includes a recycling element, although the University of Bath ICE system gives 1.93 kg/kg for building papers. Since the items also need to cut and formed, this adds an unknown amount, but let us provisionally double the government value to 1.68. This would give a total of **198.24 kgCO2e** for single-use paper plates, although it could be considerably higher or lower.

It is hard to find reliable data on the carbon intensity of wooden utensils, but we should assume a certain amount of processing is required to cut and form the pieces. Perhaps hardboard is the closest, with a rather high intensity of 0.54 kg/kg. Applying this, we have 31.5\*0.54 = **17.0 kgCO2e** for wooden utensils.

We have to consider transport for the waste plates and cutlery, a small fraction of the general waste stream. Assume that all this waste is hauled 20 miles at 300 g/mile = **6 kgCO2e**.

Finally the waste goes to an Energy from Waste Incineration (EfWI) plant, say 20 miles away. There it is combusted and (typically) 20% of the embodied energy is recovered as electricity. If paper has a calorific value of 5.1 kWh/kg and wood 4.5 kWh/kg, the total energy content of the waste stream is 118\*5.1+47.2\*4.5 = 814.2 kWh, of which 20% is 162.8 kWh. This displaces grid electrcicity at 0.34 kg/kWh = **-55.3 kgCO2e**

The totals then are 198 + 17 + 6 – 55 = **166 kgCO2e per festival**.

GHGE PER PAPER PLATE MEAL ARE **21 gCO2e**

DISCUSSION

Comparing the two years on an ‘as was’ basis, the paper plates emerge victorious, but – if the ‘as reported’ assumptions are made -- not by much. Note we have neglected transport of the various items to the SF site, assuming they cancel out. Steel plates are presumably made in China while the paper plates come from Norway. These factors are unlikely to make much difference.

Given that we are generally biased towards re-use systems, is there any change that could bring the reusable plates carbon scores down?

There is one obvious change, and that is to cut out the users’ pre-rinse step. Even theoretically, if this component is discounted it removes the uncertainty over the 2018 system, which is largely due to the pre-rinse step. This step is hard to control and tends to be wasteful, both of water and energy. It would have to be replaced by standard pre-rinsing using Pressurised spray valves (PRSVs) operated by trained staff. This is favoured by catering staff, who are also concerned about contamination from *Escherichia coli* if untrained users are involved in any of the cleaning processes. The EHO would probably be pleased as well.

Examine this alternative option. Users scrape their plates and stack them. This is good because the food residues do not dry on. The plates are then removed to the washing area where the PRSVs are set up. The plates are then processed and the dishwasher stacked as before. With 12 plates per rack there are 10-20 cycles per meal. The operator can pre-rinse plates while the machine is washing a batch, and presumably can easily do it within the 3-minute cycle. PRSVs vary a lot, but the ‘eco’ ones generate 6 L per minute at around 40°C. Let us say that an operator can pre-rinse 12 plates and 24 pieces of cutlery in 2 minutes. We have 2\*6 = 12 litres per cycle, raised through 22°C. I calculate this would take 202 kWh. If supplied using propane at 80% efficiency, this would be equivalent to 54.8 kgCO2e, while saving 14.9 kL of water.

This means that the steel plate system would be reduced from 256 to 188 kgCO2e, giving 24 gCO2e per meal, almost as good as the paper plates. This result is of course sensitive to unknowns, notably if the rinsing system were faster than 2 minutes per cycle. If it could be done in 90 seconds the recyclable plate emissions would be lower than the single-use plates.

EFFECTS OF THE NO-MEAT POLICY

Carbon emissions and savings from dietary changes can be roughly compared with the eatware systems, simply by taking the same number of meals served to Crew and assuming different dietary mixes.

At CAT we modelled a number of standardised diets using varying proportions of foods with known carbon intensities. After various correction procedures we characterised the ‘standard diet’ as having GHGE of 983 g/day. The SF is ‘meat free’ but that still covers a wide range of possibilities. The closest to what has been happening at the SF are what we called ‘substitute lacto’ and ‘light lacto’.

‘Substitute lacto’ is a diet that is often followed by those with standard British dietary habits suddenly ceasing to eat meat. They feel that a meal must be built around some animal source of protein, and without meat this defaults to eggs and egg dishes, and cheese and other dairy products. The total quantity of animal protein is the same as before, but without actual meat. It is not surprising perhaps, that this makes little difference to the carbon emissions, 848 g/day or 86.3% of the dietary standard.

‘Light lacto’ does still use eggs and dairy, but very sparingly. As we modelled it, the result was 485g/day, less than 50% of the standard. Observing the canteen food at the SF it is obviously far closer to the Light Lacto pattern than to the substitute lacto, so let us use this as a model.

For 9832 meals, assuming three meals a day, that is 9832\*485/3 = 1.59 tCO2e, compared with the standard diet which would have been 3.22 tCO2e. We could say then, that for the Crew, the dietary change saved 1630 kgCO2e. This is much larger than the reductions arising from eatware processing. It is perhaps worth remarking that if the staff canteen went entirely vegan, the emissions would be only 688 kgCO2e, saving 2.53 tCO2e relative to a standard diet, or 900 kg relative to the present arrangement. This compares with a difference of 81 kg for the eatware systems.

Across the festival as a whole, assuming 4 days and 20,000 people, a dietary change to ‘light lacto’ (which is probably close to the actual case) saves more than 100 tonnes CO2e relative to standard food.

1. The official symbol for litres is a lower case ‘l’ but this is easily confused with the figure 1, so for clarity I shall use an upper-case L. The symbol kL is a kilolitre or one thousand litres or one cubic metre of water weighing exactly one metric tonne. One litre weighs one kilogram. [↑](#footnote-ref-1)