

WOMADelaide Project- Data Analysis

Rachel Leung, University of Adelaide, Adelaide, South Australia.

1. Introduction

1.1 Objective

The goal of this data analysis was to study the environmental impact of replacing single use cups with reusable cups at the WOMADelaide festival.

1.2 Scope of Data Analysis

This analysis compares the energy and water consumption of single use (compostable) cups and reusable cups. The comparison is split into two components as stated below:

- i) Upfront energy and water consumption of producing single use cups vs reusable cups
- ii) The energy and water required for cleaning reusable cups vs producing equivalent number of single use cups

2. Methodology

2.1 Background

The single use compostable cups purchased by WOMADelaide are provided by Pak Rite, a South Australian based company that specialises in a range of environmentally friendly products. The single use compostable cups are made of Ingeo Polyactic Acid (PLA) biopolymers, which are supplied by BioPak (Richard Fine, personal communication, 6 February 2017). 160,000 single use PLA cups were purchased by WOMADelaide in 2016 (Mark Muller, personal communication, 20 December 2016). Data outlining the energy and water consumption associated with the production of a single use PLA cups is available in Appendix A.

Globelet is a New Zealand based company that provides renting and cleaning service of reusable cups for different events including music festivals. Globelet is implementing a plant and 4 different washing centres across Australia in 2017. The Globelet Original cup is used as a case study for this analysis. The estimated lifespan of a Globelet Original is 100 - 1000 washes (Ryan Everton, personal communication, 9 March 2017). It can be recycled in the Globelet factory or public recycling plants (Ryan Everton, personal communication, 9 March 2017). Data outlining the energy and water consumption associated with the production and washing of a Globelet Original cup is available in Appendix B.

2.2 Breakdown of Production Cycle

The energy and water consumption of the production cycles for single use PLA cups and the Globelet Original reusable cups can be broken down as follows:

Single use PLA Cups:

1. Manufacture the Polylactic Acid (PLA) biopolymers
2. Thermoform Polylactic Acid biopolymers into cups
3. Transport cups to event venue

Globelet Original reusable cups:

1. Manufacture the Globelet Original Cups
2. Transport reusable cups to event venue
3. Wash cups at the washing station

3. Assumptions

Several assumptions have been made to address the limitations of the study as listed below:

1. Both Globelet cups and Ingeo PLA cups were produced locally in South Australia.
2. Energy consumption associated with transportation was excluded from the scope.
3. All data provided by BioPak and Globelet is accurate and reliable
4. 20,000 Globelet cups are sufficient to replace 160,000 single use PLA cups with the Globelet cups being washed twice a day during the festival

4. Results

A summary of the energy and water consumption for single use PLA cups and Globelet Original is displayed in table 1 and 2. Globelet Original cups consume more energy than single use PLA cups as displayed in figure 1. This is due to their high upfront energy consumption as they are designed to be durable for reusing up to 1000 times.

The single use PLA cups consume more water than the Globelet Original as displayed in figure 2. The Globelet Original recycle all water during the manufacturing process, which reduces their water footprint significantly. Detailed calculations of total energy and water consumption of single use PLA cups and Globelet Original are provided in Appendix C.

Table 1. Summary of energy consumption for PLA cups and Globelet Original Cups

	Single use PLA cups	Globelet Original Cups
Upfront energy consumption (MJ)	69482.88	65000
Energy required to wash cups (MJ)	-	9600
Total energy consumption (MJ)	69482.88	74600

Table 2. Summary of water consumption for PLA cups and Globelet Original Cups

	Single use PLA cups	Globelet Original Cups
Upfront water consumption (L)	60480	-
Water required to wash cups (L)	-	9600
Total water consumption (L)	60480	9600

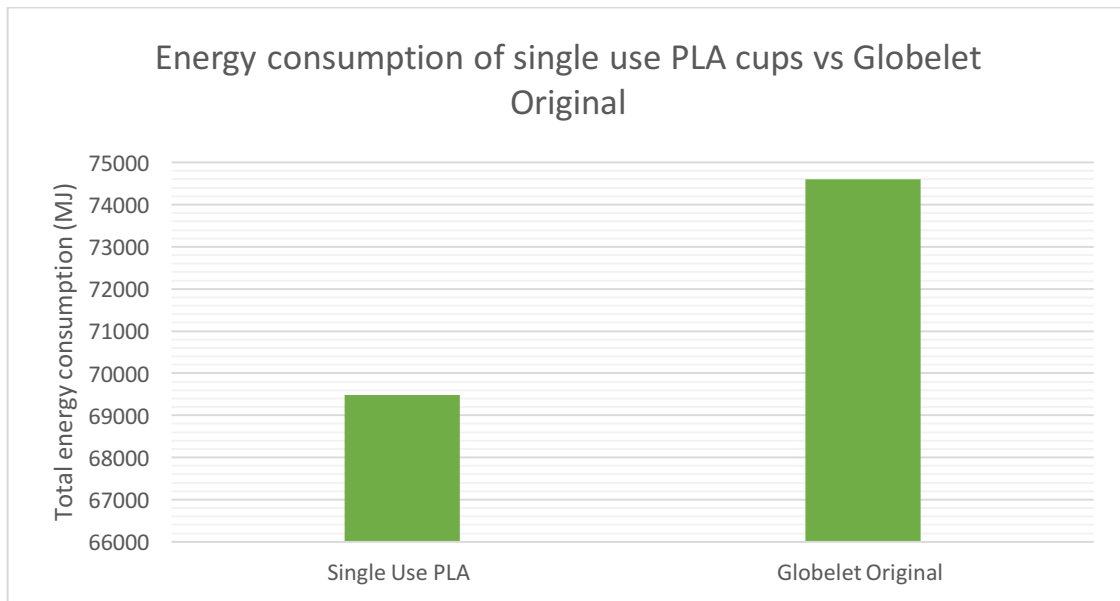


Figure 1. Energy consumption of single use PLA cups vs Globelet Original

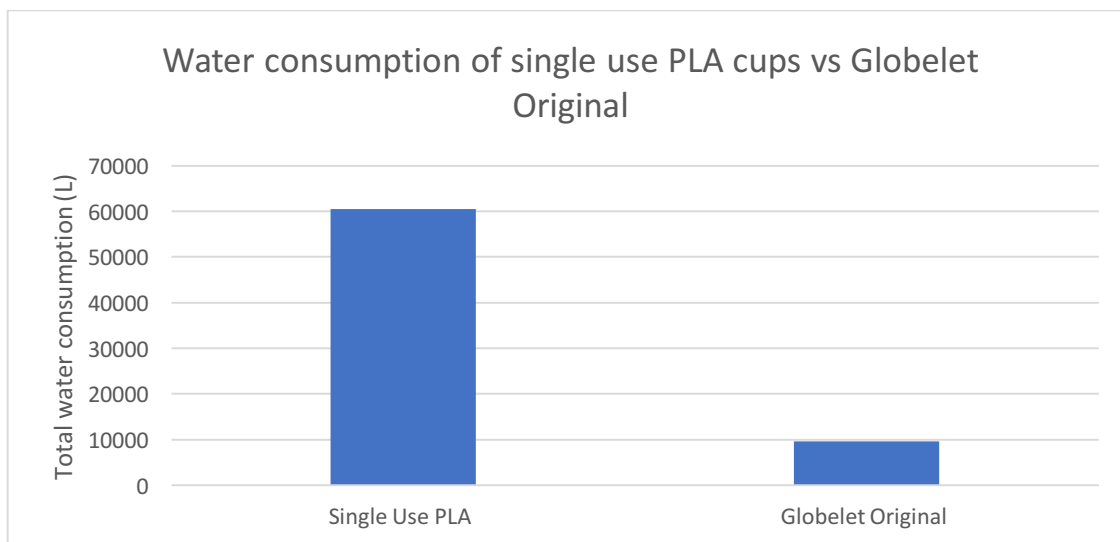


Figure 2. Water consumption of single use PLA cups vs Globelet Original

A summary of the energy and water consumption for single use PLA cups and Globelet Original for two festivals (8 days) is displayed in table 3 and 4. Figure 3 shows that total energy required for the Globelet Original is lower than single use PLA cups. This indicates that the total energy required for the Globelet Original from prolonged use outweighs its high upfront energy consumption. It can be concluded that reusing the Gobelet Original for multiple festivals is more energy efficient than purchasing Single Use PLA cups.

The total water consumption for single use PLA cups is consistently greater than the Globelet Original cups as displayed in Figure 2 and 4. Assuming an average shower uses 65.1L of water (Alliance for Water Efficiency 2017), switching to reusable cups for two festivals can save water for up to 1563 showers (see Appendix C).

Table 3. Summary of energy consumption for PLA cups and Globelet Original Cups supply for two festivals (8 days)

	Single Use PLA cups	Globelet Original Cups
Upfront energy consumption (MJ)	138965.76	65000
Energy required to wash cups (MJ)	-	19200
Total energy consumption (MJ)	138965.76	84200

Table 4. Summary of water consumption for PLA cups and Globelet Original Cups supply for two festivals (8 days)

	Single Use PLA cups	Globelet Original Cups
Upfront water consumption (L)	120969	-
Water required to wash cups (L)	-	19200
Total water consumption (L)	120969	19200

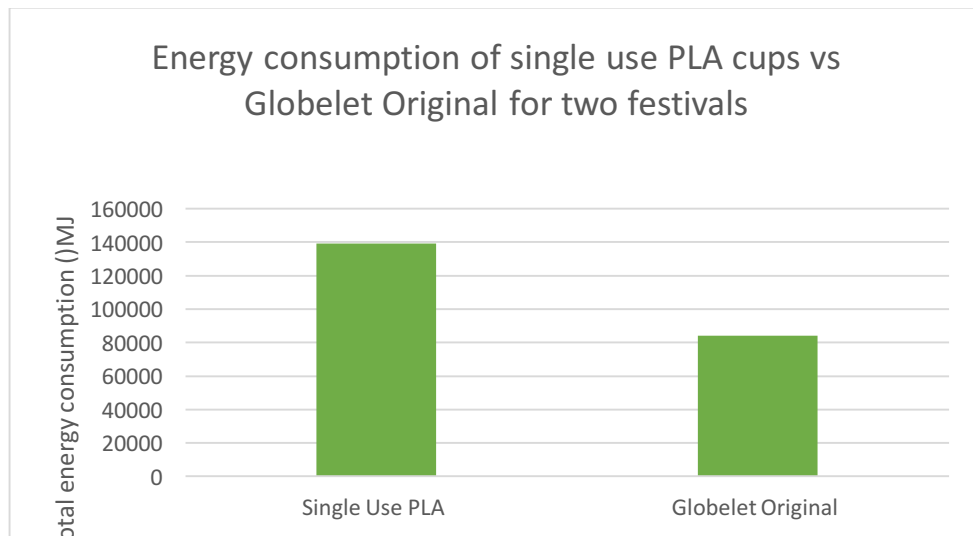


Figure 3. Energy consumption of single use PLA cups vs Globelet Original for two festivals

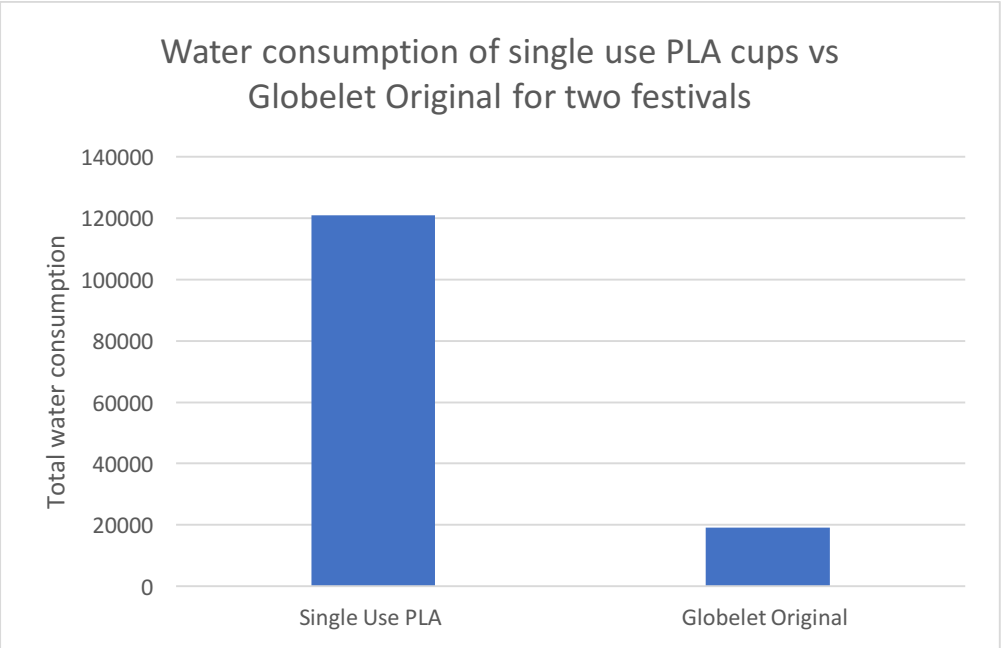


Figure 4. Energy consumption of single use PLA cups vs Globelet Original for two festivals

5. Conclusion

Analysis of the energy and water consumption for single use PLA cups and the Globelet Original cups was conducted. The analysis showed that the manufacturing and washing processes of the Globelet Original were consistently more water efficient than single use PLA cups. It was concluded that reusing the Gobelet Original for multiple festivals is more energy efficient than purchasing Single use PLA cups.

6. Referencing

Alliance for Water Efficiency 2017, *Showering to Savings*, Alliance for Water Efficiency, viewed 9th July 2017, <<http://www.home-water-works.org/about>>

Appendix A- Data provided by BioPak

- A 425ml compostable cup weights 10.8 grams
- The energy and water required to produce Ingeo polymer can be found on page 175 of Ingeo PLA cups document attached (see next page).
- The energy used for the thermoforming of 1 kg of PLA, PET and PS sheets into cups was calculated to be 0.21, 0.31, and 0.30 MJ, respectively. The calculations were material specific and not machine-specific.
- Water is not consumed during the production of cups as its only used for cooling and the water used for this recycled in a closed loop at the factory.

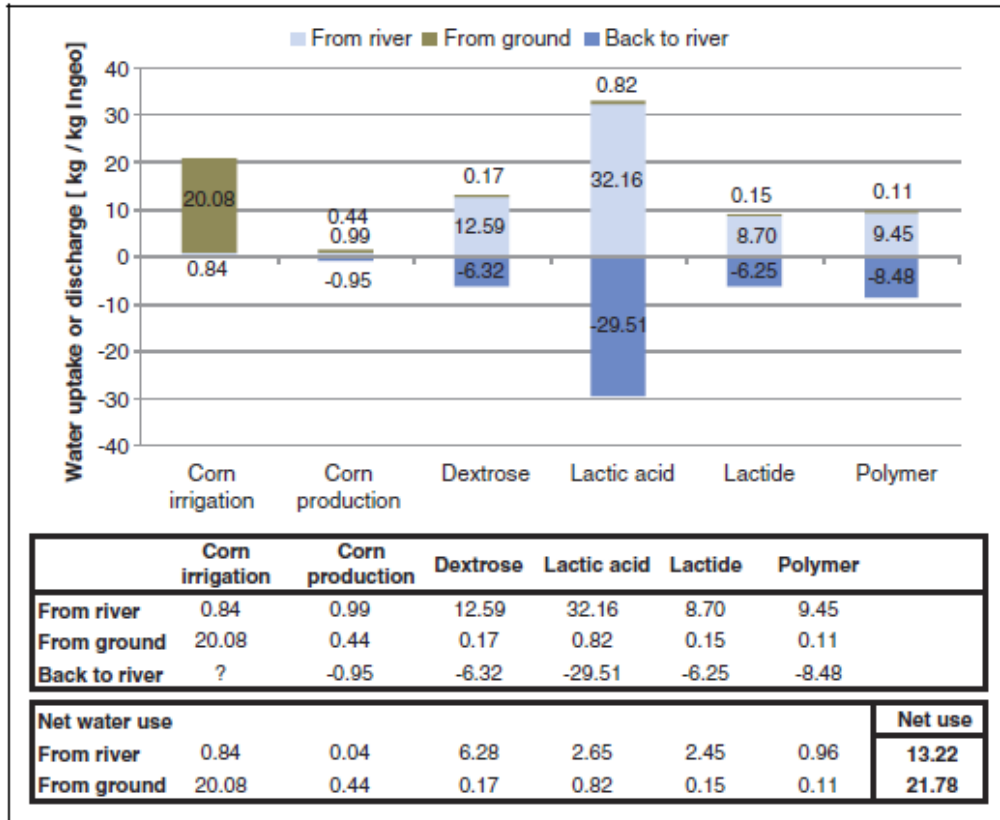


Fig. 10. Water-use balance in the Ingeo biopolymer production system.

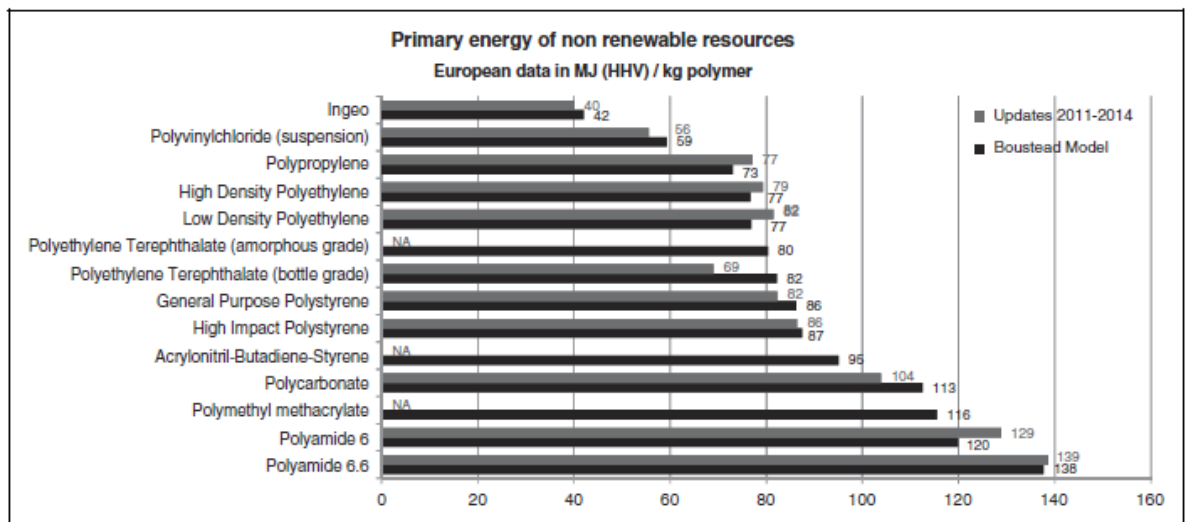


Fig. 11. European data; primary energy of nonrenewable resources (MJ/kg polymer, using HHV). Fossil-based polymer data from PlasticsEurope.

Appendix B- Data provided by Globelet

Globelet Original:

Manufacturing:

- The estimated lifespan of a Globelet Original is 100 - 1000 washers (4 years)
- The print is normally the first thing to go. They can strip and reprint this to give it a second life.
- If a Globelet Original is returned to the factory, which they recycle it there. Otherwise it is classed at #5 in main stream
- The Globelet Original's weight is 30 grams• The Globelet Original's recycles all water during manufacturing process
- The energy required to produce a Globelet Original is 2500-4000 kj/cup (4 cavity vs 2 cavity tool dependent + machine used)

Washing:

Globelet have 5 dishwashers. Each Machine has different energy and water usage requirements. Globelet only has proper stats on their Hobart one as they recently required 3 new ones.

Dishwashers at Hobart:

- The technical characteristics of the cups mean that they can wash them using 6 cl of water
- The machine has a 63 kw connection.- The washer and dryer both draw 50 amps of electricity in total
- Energy per cup is 40-80 KJ to wash (depends on how many cups they can drive through conveyor)
- They can wash 3000 - 5000 cups per hour (80 per minute)

Appendix C - Calculations

- ⇒ Number of Single Use PLA cups purchased by WOMAD (including bars and others) = 160,000
- ⇒ Assuming the Globelet Original cups used to replace the single use cups will be washed twice a day, 20,000 Globelet cups are required to meet the demand of the festival

Single Use PLA cups:

1.) Upfront energy consumption:

$$\text{Energy required to produce 1 kg of Ingeo PLA} = 40 \frac{\text{MJ}}{\text{kg}}$$
$$= 40 \times 10^6 \frac{\text{J}}{\text{kg}}$$

$$\text{Weight of one PLA cup} = 10.8 \text{ g/cup}$$
$$= 0.0108 \text{ kg/cup}$$

Energy required to produce Ingeo PLA for one PLA cup, E_{material} :

$$E_{\text{material}} = 40 \times 10^6 \frac{\text{J}}{\text{kg}} \times 0.0108 \frac{\text{kg}}{\text{cup}}$$

$$E_{\text{material}} = 432,000 \frac{\text{J}}{\text{cup}}$$

$$E_{\text{material}} = 432 \frac{\text{kJ}}{\text{cup}}$$

$$\text{Energy required to thermoform 1 kg of PLA} = 0.21 \frac{\text{MJ}}{\text{kg}}$$
$$= 0.21 \times 10^6 \frac{\text{J}}{\text{kg}}$$

Energy required to thermoform one PLA cup, E_{thermo} :

$$E_{\text{thermo}} = 0.21 \times 10^6 \frac{\text{J}}{\text{kg}} \times 0.0108 \frac{\text{kg}}{\text{cup}}$$

$$E_{\text{thermo}} = 2268 \frac{\text{J}}{\text{cup}}$$

$$E_{\text{thermo}} = 2.268 \frac{\text{kJ}}{\text{cup}}$$

Total energy required to produce one PLA cup, E_{Total} :

$$E_{\text{Total}} = E_{\text{material}} + E_{\text{thermo}}$$

$$E_{\text{Total}} = 432 \frac{\text{kJ}}{\text{cup}} + 2.268 \frac{\text{kJ}}{\text{cup}}$$

$$E_{\text{Total}} = 434.268 \frac{\text{kJ}}{\text{cup}}$$

Total energy required to produce 160,000 PLA cups, E_{Total} :

$$E_{\text{Total}} = 434.268 \frac{\text{kJ}}{\text{cup}} \times 160,000 \text{ cup}$$

$$E_{\text{Total}} = 69,482.88 \text{ MJ}$$

2.) Upfront Water consumption:

$$\begin{aligned} \text{Water required to produce 1 kg of Ingeo PLA} &= (13.22 + 21.78) \frac{\text{L}}{\text{kg}} \\ &= 35 \frac{\text{L}}{\text{kg}} \end{aligned}$$

Water required to produce PLA for one PLA cup, W_{material} :

$$\begin{aligned} W_{\text{material}} &= 35 \frac{\text{L}}{\text{kg}} \times 0.0108 \frac{\text{kg}}{\text{cup}} \\ W_{\text{material}} &= \underline{0.378 \frac{\text{L}}{\text{cup}}} \end{aligned}$$

Based on the information provided by Bio Pak, water is not consumed during the production of cups as it is only used for cooling. The water used is recycled in a closed loop at the factory.

$$\therefore W_{\text{thermo}} = 0 \frac{\text{L}}{\text{cup}}$$

Total water consumption for producing one PLA cup, W_{total} :

$$W_{\text{total}} = W_{\text{material}} + W_{\text{thermo}}$$

$$W_{\text{total}} = \underline{0.378 \frac{\text{L}}{\text{cup}}}$$

Total water consumption for producing 160,000 PLA cups, W_{total} :

$$W_{\text{total}} = 0.378 \frac{\text{L}}{\text{cup}} \times 160,000 \text{ cup}$$

$$W_{\text{total}} = \underline{60480 \text{ L}}$$

Reusable Cups - Globelet Original cups:

1.) Total energy consumption:

$$\text{Energy required to produce a Globelet Original cup} = 2500 - 4000 \frac{\text{kJ}}{\text{cup}}$$

Take the average of the range:

$$\bar{E}_{\text{upfront}} = \frac{2500 + 4000}{2} = 3250 \frac{\text{kJ}}{\text{cup}}$$

Energy required to produce 20,000 Globelet Original cup, E_{upfront} :

$$E_{\text{upfront}} = 3250 \frac{\text{kJ}}{\text{cup}} \times 20,000 \text{ cup}$$

$$\underline{E_{\text{upfront}} = 65000 \text{ MJ}}$$

Energy required to wash one Globelet Original cup ^{once} = 40 - 80 $\frac{\text{kJ}}{\text{cup}}$

Take the average of the range:

$$\bar{E}_{\text{wash}} = \frac{40 + 80}{2} = 60 \frac{\text{kJ}}{\text{cup}}$$

Energy required to wash 20,000 Globelet Original cups 8 times, E_{wash}

$$E_{\text{wash}} = 60 \frac{\text{kJ}}{\text{cup}} \times 20,000 \text{ cup} \times 8$$

$$\underline{E_{\text{wash}} = 9600 \text{ MJ}}$$

Total energy consumption, E_{total} :

$$E_{\text{total}} = E_{\text{upfront}} + E_{\text{wash}}$$

$$E_{\text{total}} = 65000 \text{ MJ} + 9600 \text{ MJ}$$

$$\underline{E_{\text{total}} = 74600 \text{ MJ}}$$

2.) Total water consumption:

Based on the information provided by Globelet, the production process of Globelet Original recycles all water during manufacturing process.

$$\therefore \text{Upfront water consumption} = W_{\text{upfront}} = 0 \frac{\text{L}}{\text{cup}}$$

Water required to wash one Globelet Original cup ^{once} = 6cl

$$= 0.06 \frac{\text{L}}{\text{cup}}$$

Water required to wash 20,000 Globelet Original cups 8 times, W_{wash} :

$$W_{\text{wash}} = 20,000 \text{ cup} \times 8 \times 0.06 \frac{\text{L}}{\text{cup}}$$

$$\underline{W_{\text{wash}} = 9600 \frac{\text{L}}{\text{cup}}}$$

Total water consumption, W_{total} :

$$W_{total} = W_{upfront} + W_{wash}$$

$$W_{total} = 0.2 + 9600L$$

$$W_{total} = 9600L$$

Consider the energy and water consumption at WOMAD for 2 festivals

$$\begin{aligned}\text{Number of Single Use PLA cups purchased by WOMAD} &= 160,000 \times 2 \\ &= 320,000\end{aligned}$$

Number of Globelet Original cups = 20,000 (remain constant)

The Globelet cups will need to be washed 16 times for 2 festivals.

Single Use PLA cups:

From previous calculations (page 1), the total energy required to produce 160,000 cups for one festival is $69,482.88 \frac{\text{MJ}}{\text{festival}}$

$$\begin{aligned}E_{\text{Total},2} &= 69,482.88 \frac{\text{MJ}}{\text{festival}} \times 2 \text{ festival} \\ E_{\text{Total},2} &= 138,965.76 \text{ MJ}\end{aligned}$$

From calculations on page 2, the total water consumption for producing cups for one festival is $60480 \frac{\text{L}}{\text{festival}}$.

The water consumption for producing cups for Two festivals, $W_{\text{Total},2}$:

$$W_{\text{Total},2} = 60480 \frac{\text{L}}{\text{festival}} \times 2 \text{ festival}$$

$$W_{\text{Total},2} = 120,960 \text{ L}$$

Globelet Original Cups:

The upfront energy consumption for producing cups supply for 2 festivals remain the same. However, the cups will be washed 16 times instead of 8 times for 2 festivals.

From previous calculations (page 3), the energy required to wash the cups 8 times is 9600 MJ/festival

The energy required for washing cups at 2 festivals, $E_{\text{wash},2}$:

$$E_{\text{wash},2} = 9600 \frac{\text{MJ}}{\text{festival}} \times 2 \text{ festival}$$

$$E_{\text{wash},2} = 19200 \text{ MJ}$$

Total energy consumption for producing and washing Globelet cups for 2 festivals:

$$E_{\text{Total}} = E_{\text{material}} + E_{\text{wash},2}$$

$$E_{\text{Total}} = 65,000 \text{ MJ} + 19,200 \text{ MJ}$$

$$E_{\text{Total}} = 84,200 \text{ MJ}$$

Similarly, the upfront water consumption remains zero. Previous calculations show that the water required to wash Globelet cups for one festival is $9600 \frac{\text{L}}{\text{festival}}$

Water required for washing Globelet cups for 2 festivals, $W_{\text{wash},2}$:

$$W_{\text{wash},2} = 9600 \frac{\text{L}}{\text{festival}} \times 2 \text{ festival}$$

$$\underline{W_{\text{wash},2} = 19200 \text{ L}}$$

Total water consumption for producing and washing Globelet cups at 2 festivals, $W_{\text{total},2}$:

$$W_{\text{total},2} = W_{\text{material}} + W_{\text{wash},2}$$

$$W_{\text{total},2} = 0 \text{ L} + 19200 \text{ L}$$

$$\underline{W_{\text{total},2} = 19200 \text{ L}}$$

Assuming the average shower uses 65.1 L of water, the number of shower that can be "saved" from switch to Reusable Globelet cups for two festivals can be calculated as follows:

$$\text{No of shower} = \frac{W_{\text{Total, PLA}} - W_{\text{Total, Globelet}}}{65.1 \frac{\text{L}}{\text{shower}}}$$

$$\text{No of shower} = \frac{120960 \text{ L} - 19200 \text{ L}}{65.1 \frac{\text{L}}{\text{shower}}}$$

$$\text{No of shower} = 1563.1 \text{ shower}$$

$$\text{No of shower} \approx 1563 \text{ showers}$$