
# Energy and $CO_2$ analysis of drinking cups

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# Outline

- Objective
- Analysis by Phase
  - Production
  - Manufacturing
  - Use
  - Disposal
- Life Cycle Assessments
- Comparison (energy and CO2)
- Conclusion

# Objective

- Compare Energy and CO2 footprints for coffee drinking cups
- Studied:
  - Polystyrene
  - Paper
  - Stainless steel
  - Glass
  - Polyethylene
- Coffee hour- is it best to bring your own dishes?

# Embedded Energy and $CO_2$

- Assumptions-
  - CES embedded energy and $CO_2$ for all materials
  - 10 oz cup weights (experimentally determined)
    - Paper 7 g
    - Polystyrene 2 g
    - Stainless Steel 120 g
    - Glass 370 g
    - Polyethylene  40 g

# Manufacturing

- Polystyrene- Expanded foam molding[1]
- Paper- from source [1,2]
- Stainless Steel- cast *(calculated)*
- Polyethylene- *Melting energy, negligible* $CO_2$
- Glass- cast/blown[1]


*1 "Reusable and Disposable Cups: An Energy-Based Evaluation" Environmental Management. Vol 18. No.6 pp 889-899.*

2 American Paper Institute. 1990. US pulp and paperboard industry's energy use, calendar year 1989, New York; cited by Wells (1991).

# Use

- Average Dishwasher
  - Reusable cups washed after *every* use
  - Energy use: ~80% water, 20% Drying[1]
  - Model uses average household water consumption and drying energy per load[2]
  - 0.06 $gCO_2$ / kJ (electric)[3]
    *assume all energy consumed is electrical*
  - Assume 50 dishes / load

- Average Wash by hand
  - Heat 1/5 gallon of water and air dry

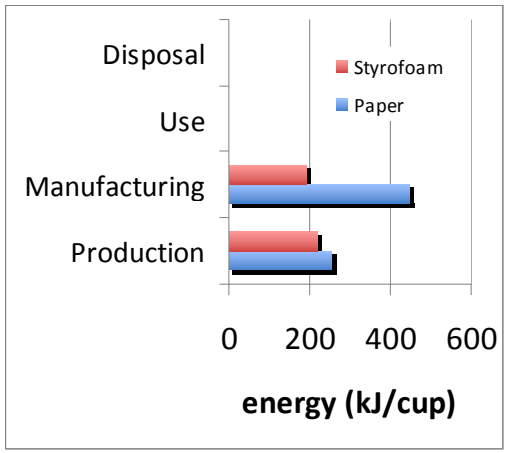
1. http://www.bchydro.com/powersmart/elibrary/elibrary705.html
2. http://www.flatheadelectric.com/energy/appliancewattage.htm
3. source: http://cdiac.ornl.gov/pns/faq.html

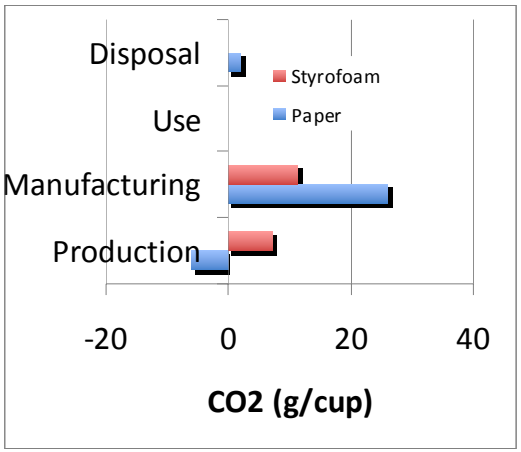
# Disposal

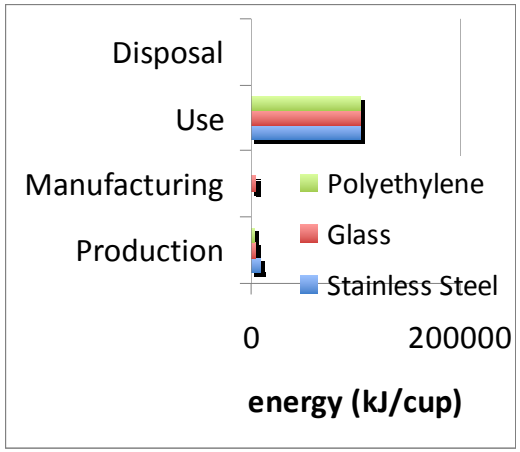
- Two Options:
  - 100% to landfill
  - 50% incinerated (η = 30%), 50% to landfill
- Sources of energy loss and $CO_2$ emission
  - Transport to landfill/incinerator
  - Energy/$CO^2$ extracted by incineration[1]
  - $CO_2$ released by decomposition (based on molecular formulas)

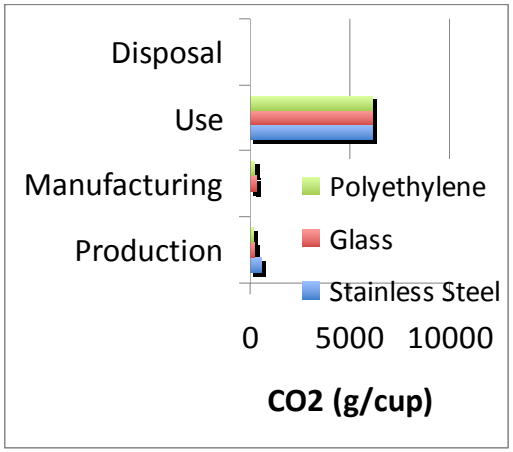
1 Hocking, M.B. 1991. Paper versus polystyrene: A complex choice. Science 251 p. 504.

# Life Cycle Assessment



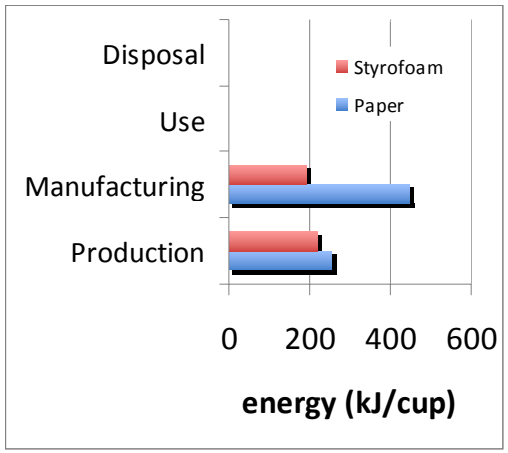



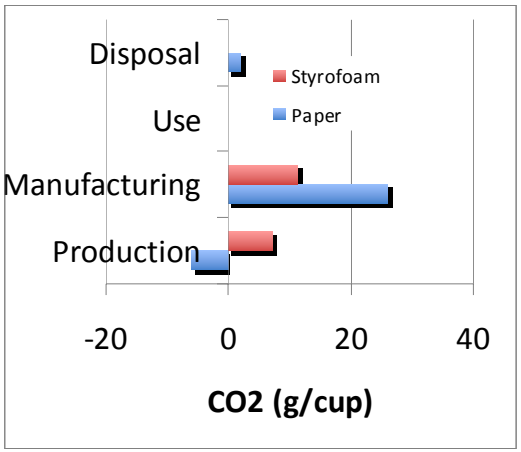



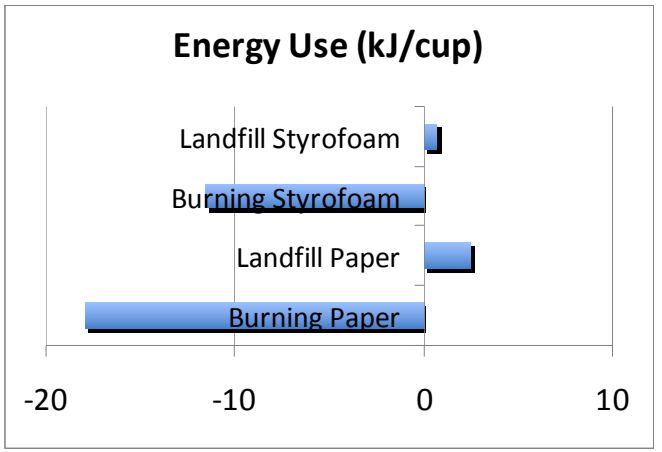



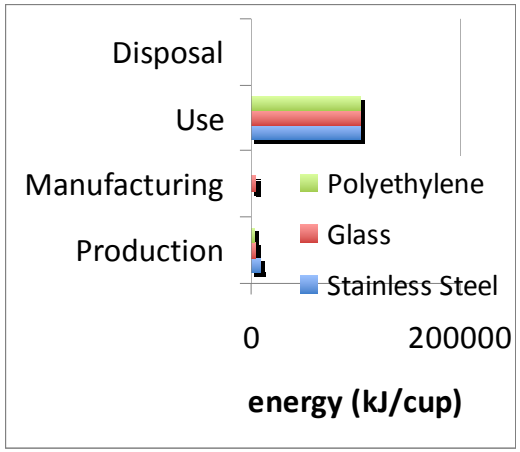
# Life Cycle Assessment

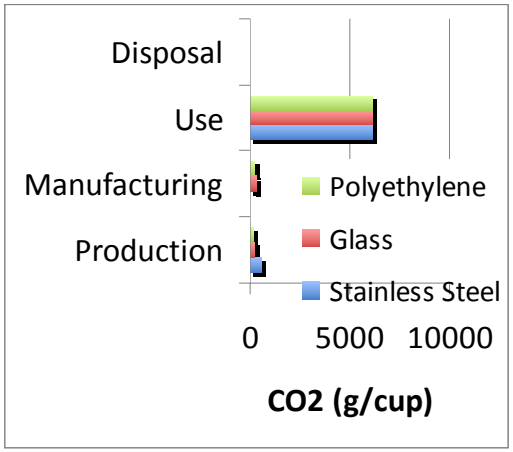
Disposables:

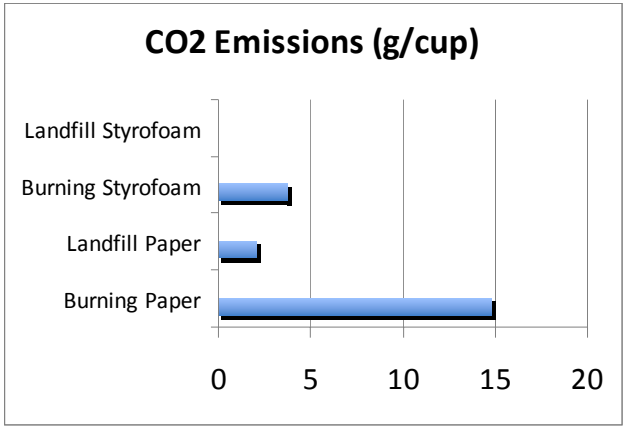


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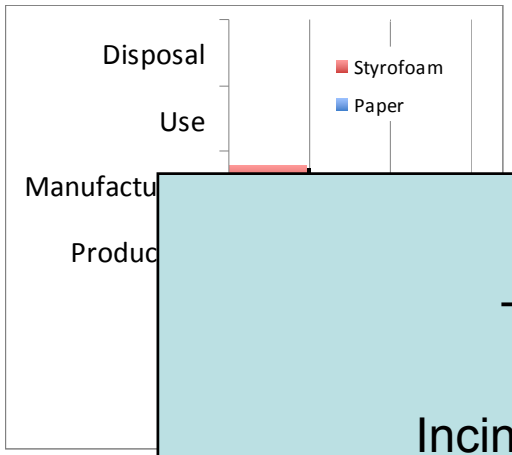
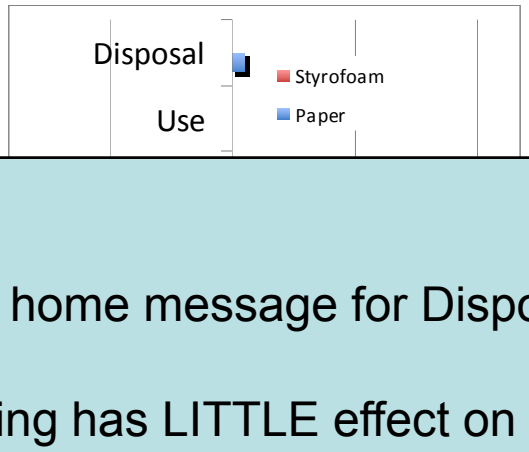
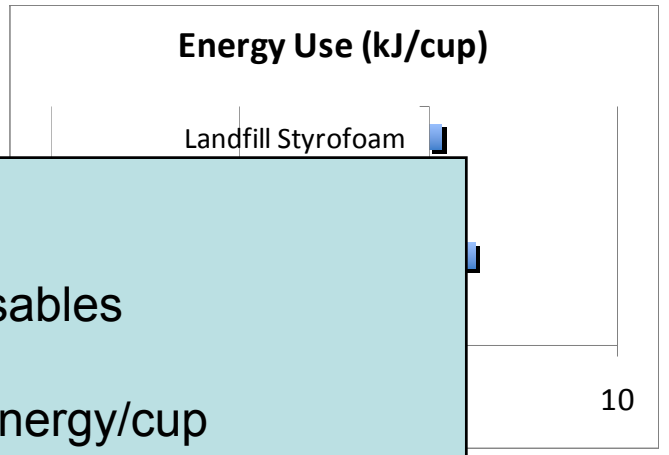
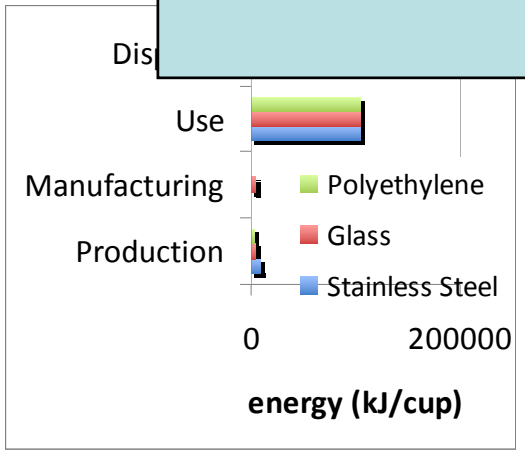


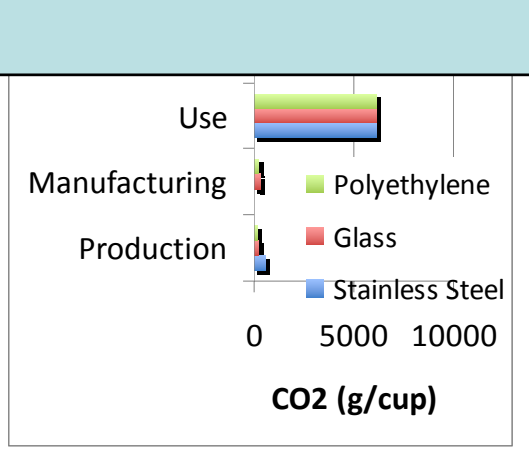



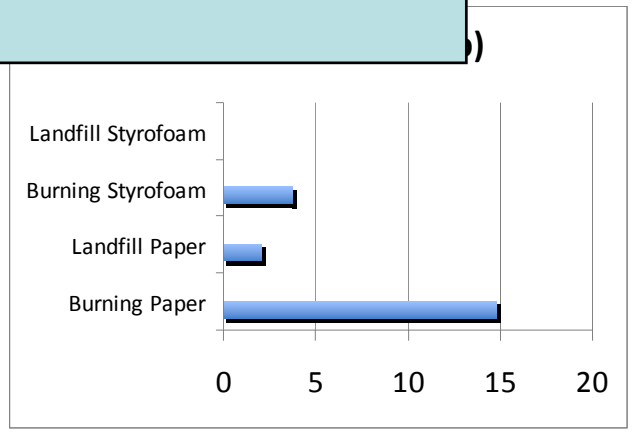




Take home message for Disposables

Incinerating has LITTLE effect on energy/cup
and LARGE effect on CO2/cup

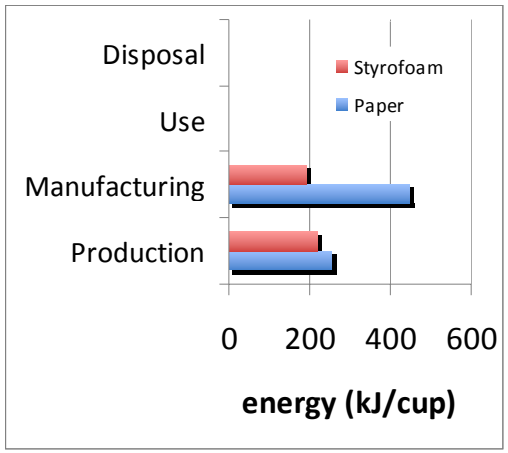


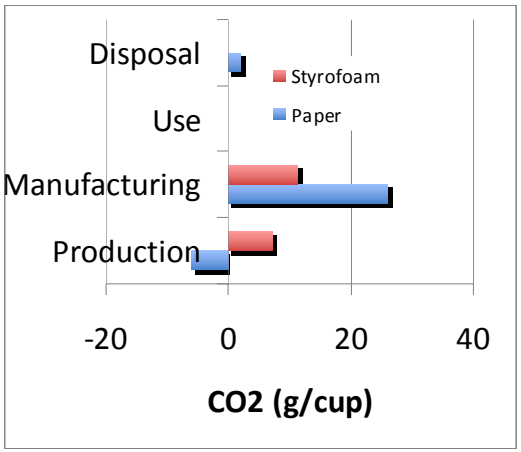



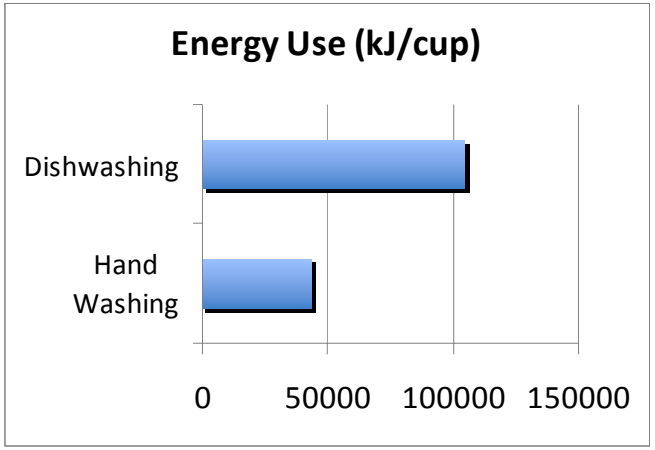



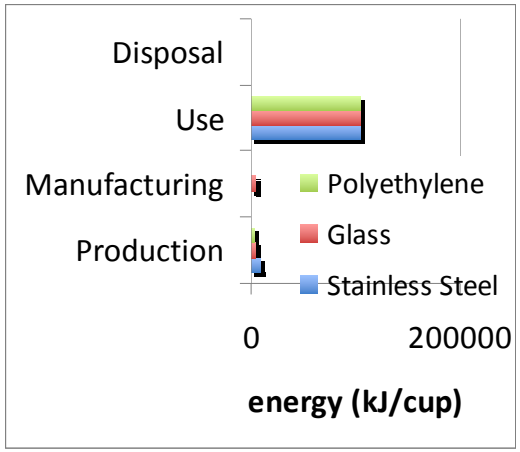
# Life Cycle Assessment

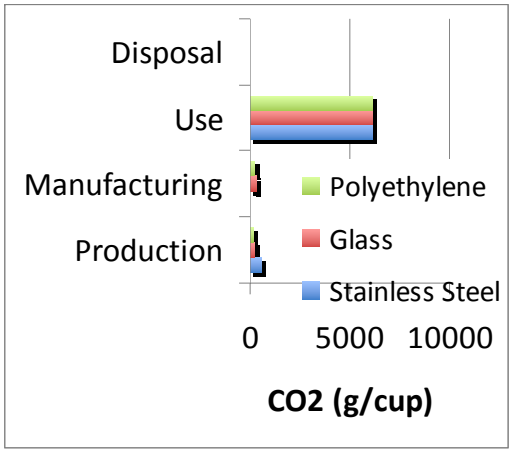
Reusables:

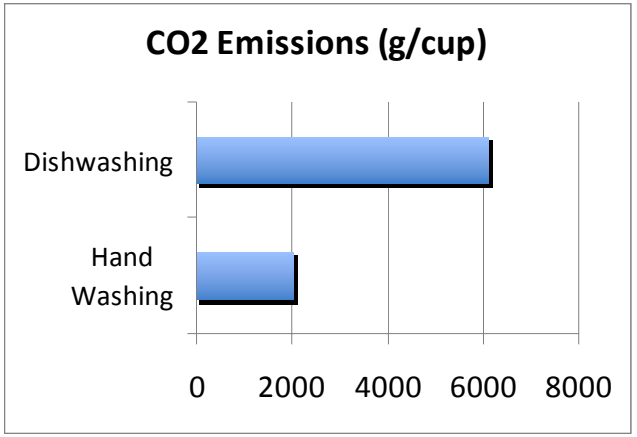


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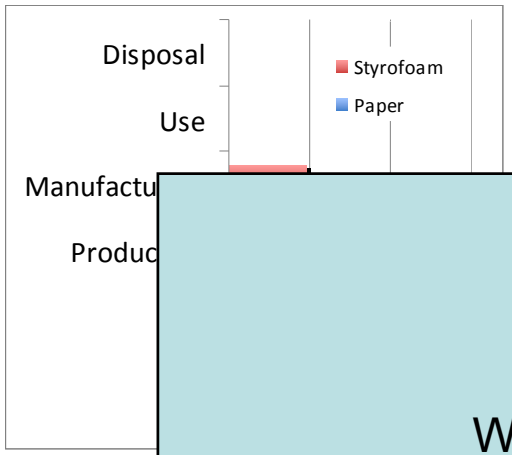
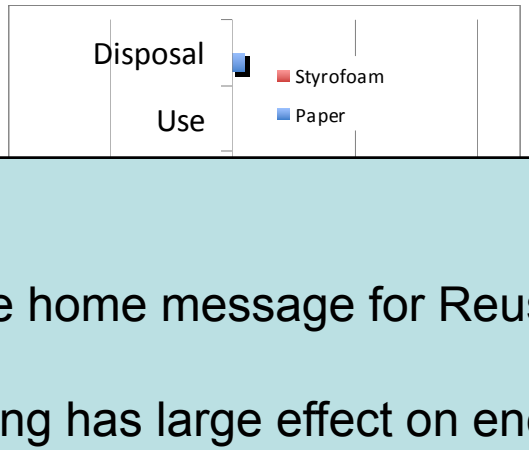
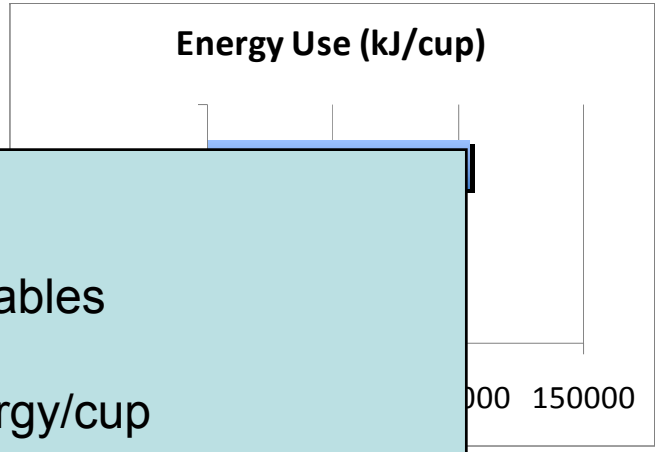
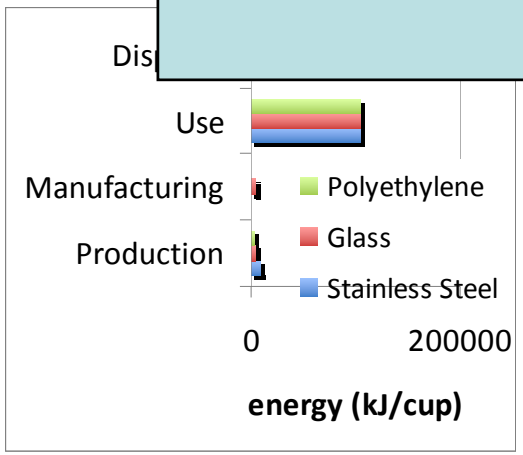


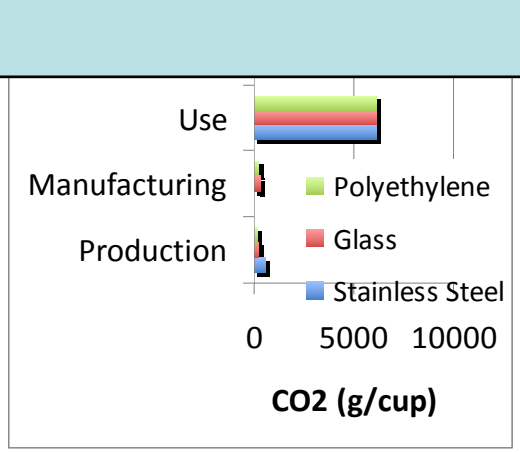



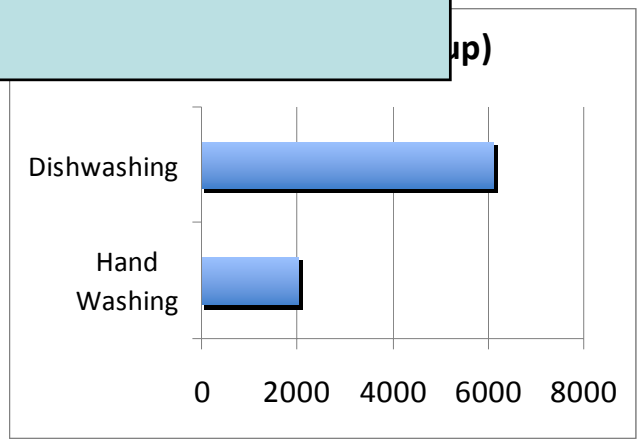




Take home message for Reusables

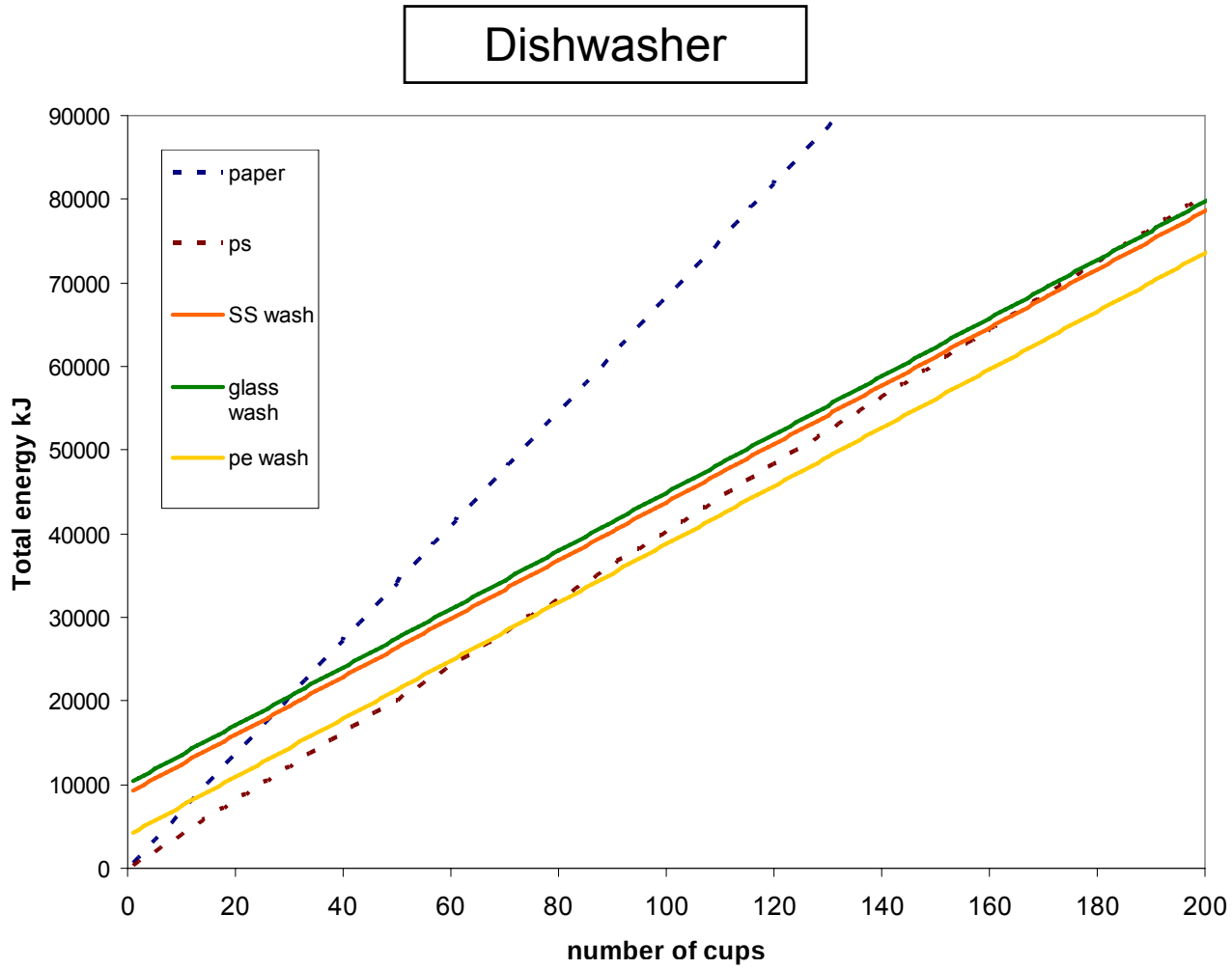
Washing has large effect on energy/cup
and LARGE effect on CO2/cup



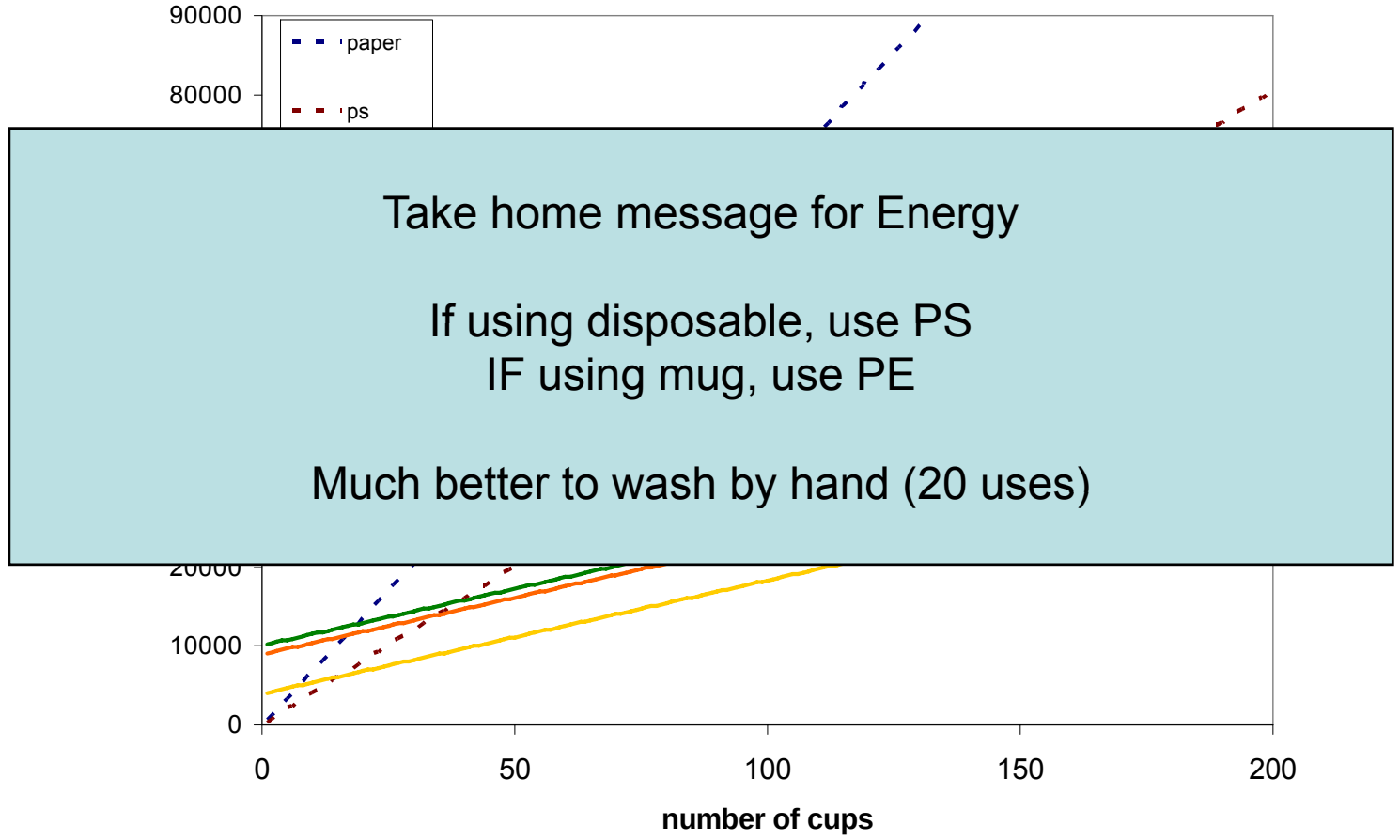
# Break-Even Energy




Literature break even: glass = 15 for paper, 390 for PS

# Break-Even Energy

Hand-washing




Take home message for Energy

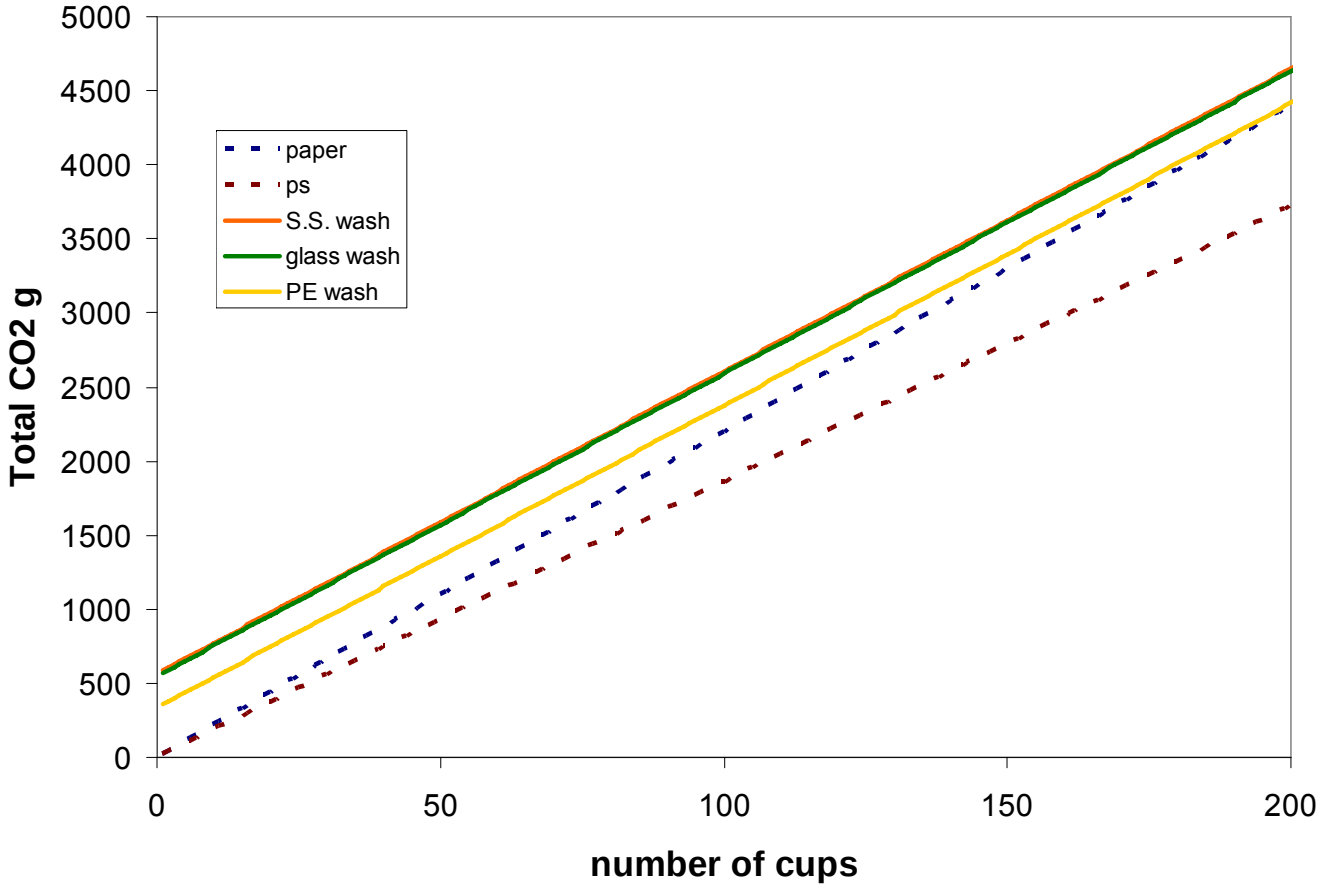
If using disposable, use PS
IF using mug, use PE

Much better to wash by hand (20 uses)

Literature break even: glass = 15 for paper, 390 for PS

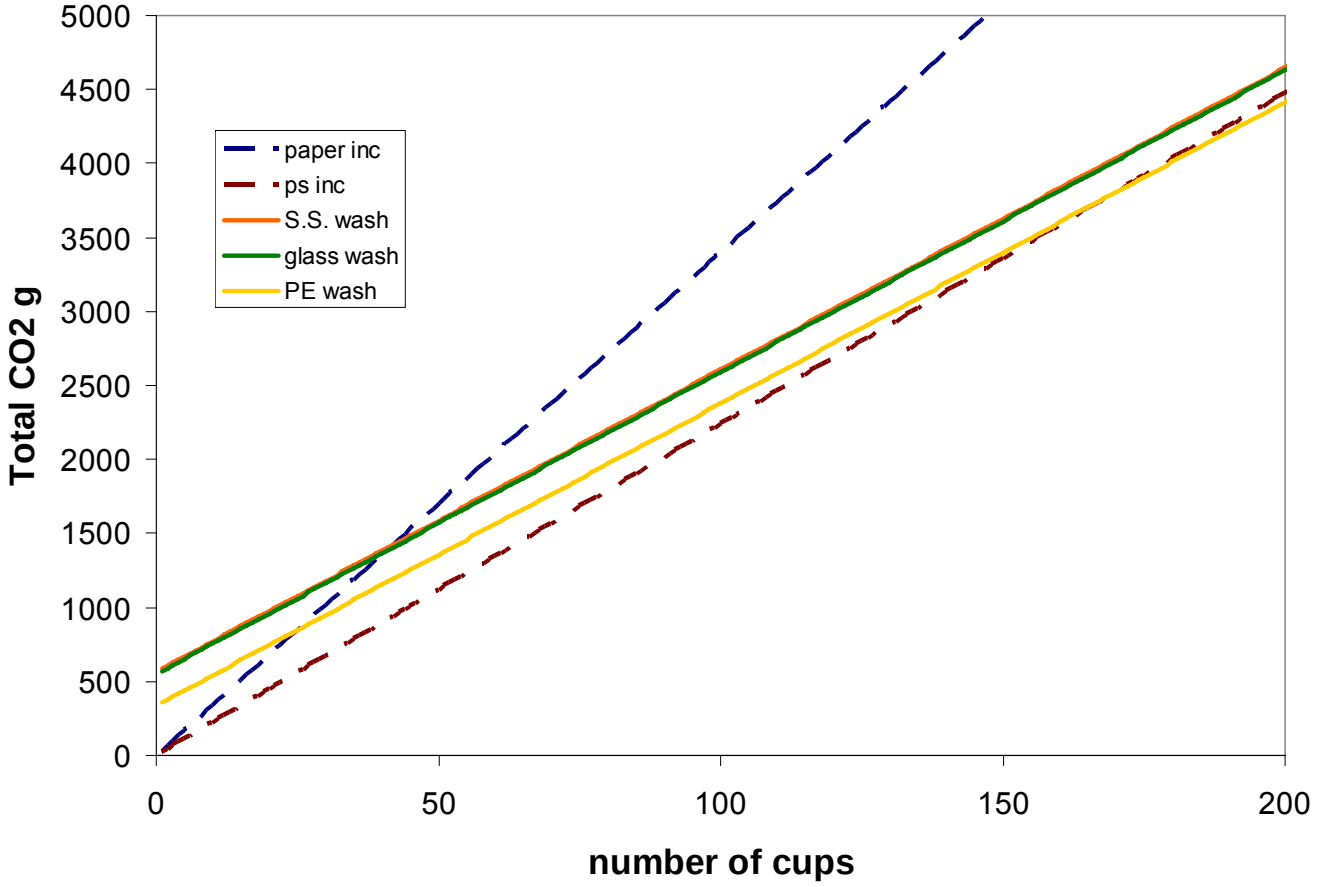
# Break-Even CO2

Dishwashing, no incineration



# Break-Even CO2

Dishwashing, w/ 50% incineration



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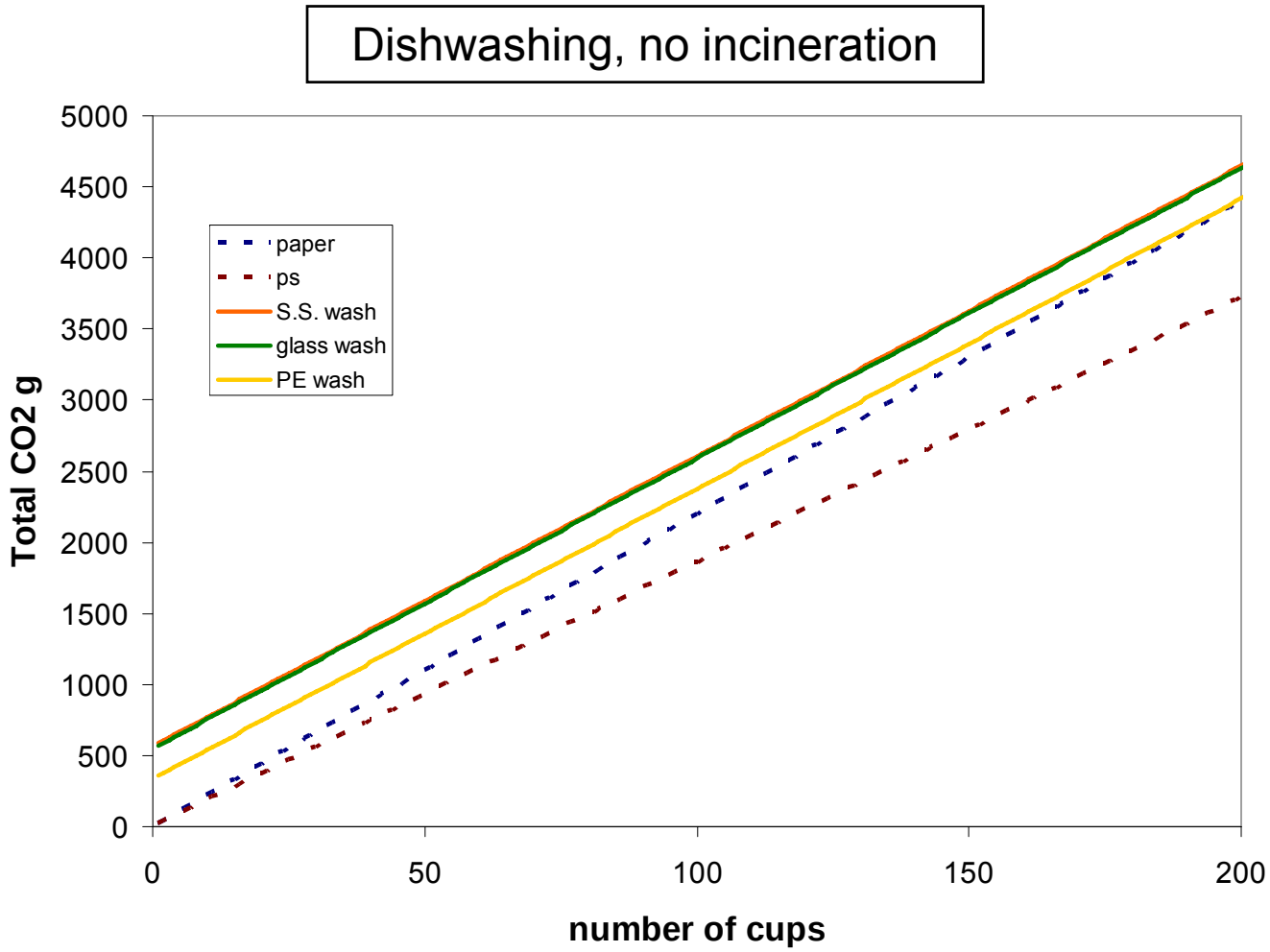

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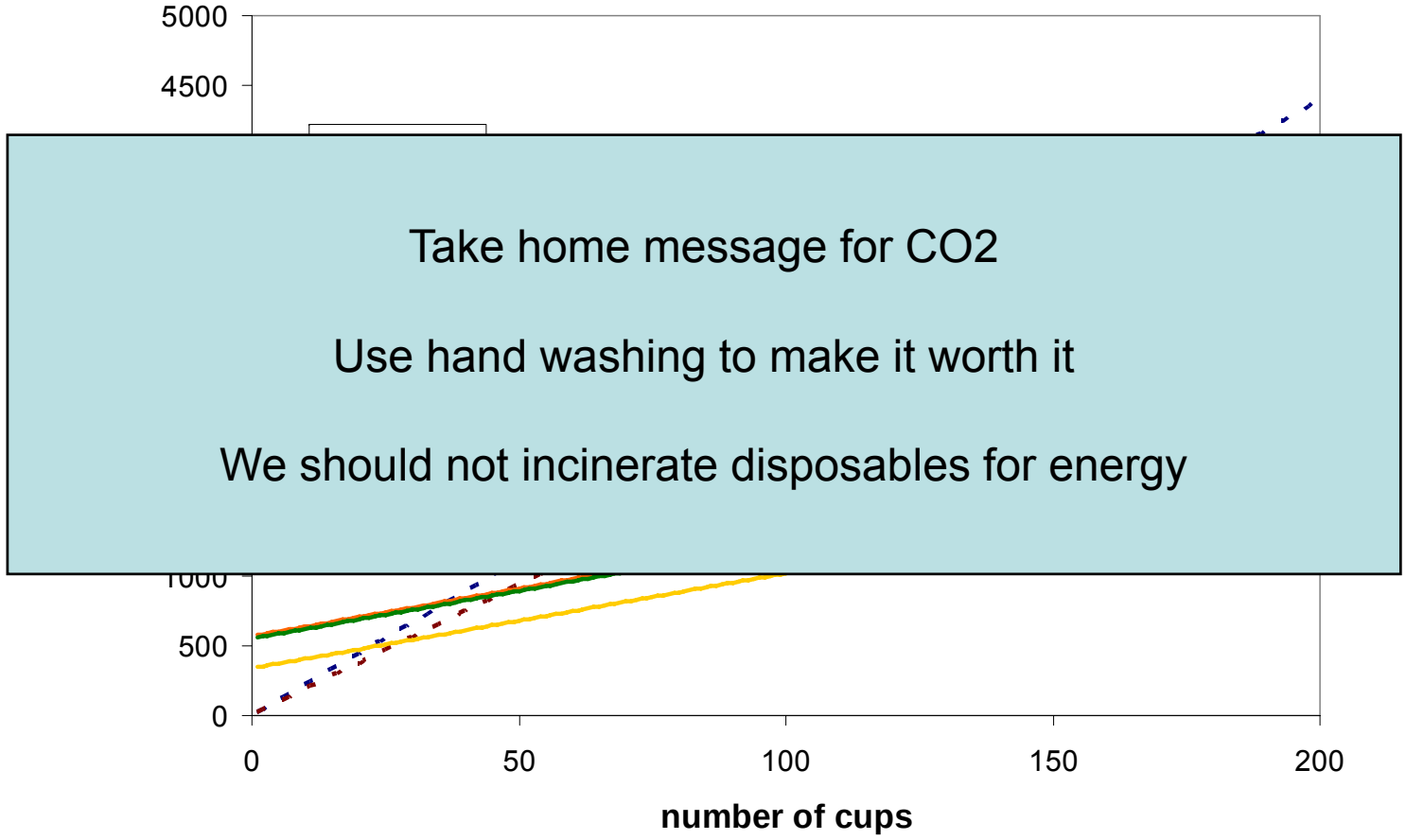



Take home message for CO2

Use hand washing to make it worth it

We should not incinerate disposables for energy

# Model Sensitivity to Assumptions

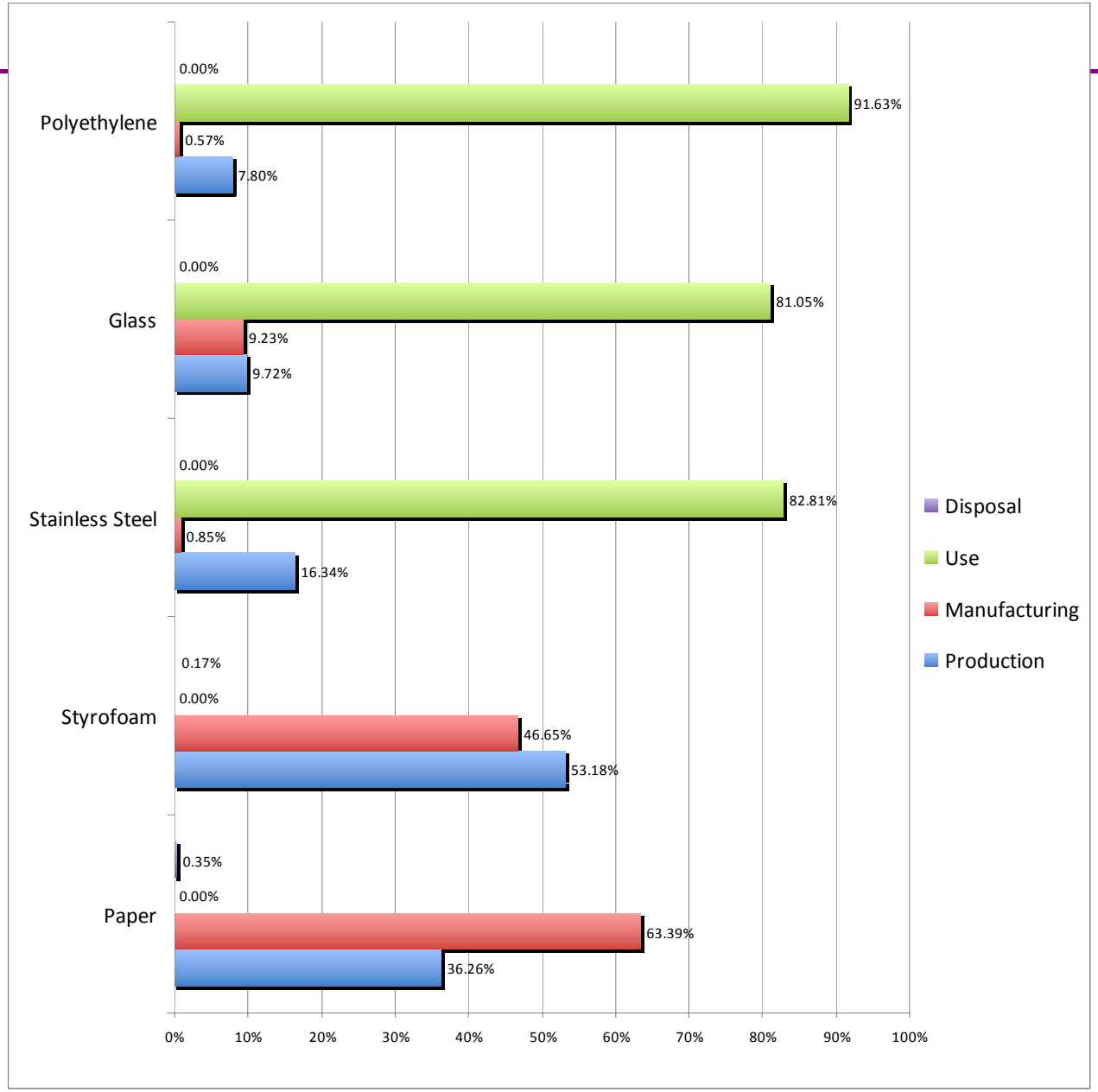
- Model is very sensitive to assumptions
- Validity:
  - Total energy in paper : 700 kJ/cup
    - Compared with 550 kJ/cup[1]
  - Total energy in PS : 400 kJ/cup
    - Compared with 200 kJ/cup[1]
  - From earlier, the number of cups required by reusables made sense with literature values
- We believe we were able to get reasonable quantitative data

# Conclusions

- Incineration of materials does not save much energy while producing a lot of CO2
  - Don't do it
- Washing mugs more economically drastically reduces the number of uses to save energy, CO2

- What types of dishes should be used for coffee hour dishes?
  - First choice- bring your own mug (if use it more than 20 times)
  - Second Choice- PS

# Life Cycle Assessment



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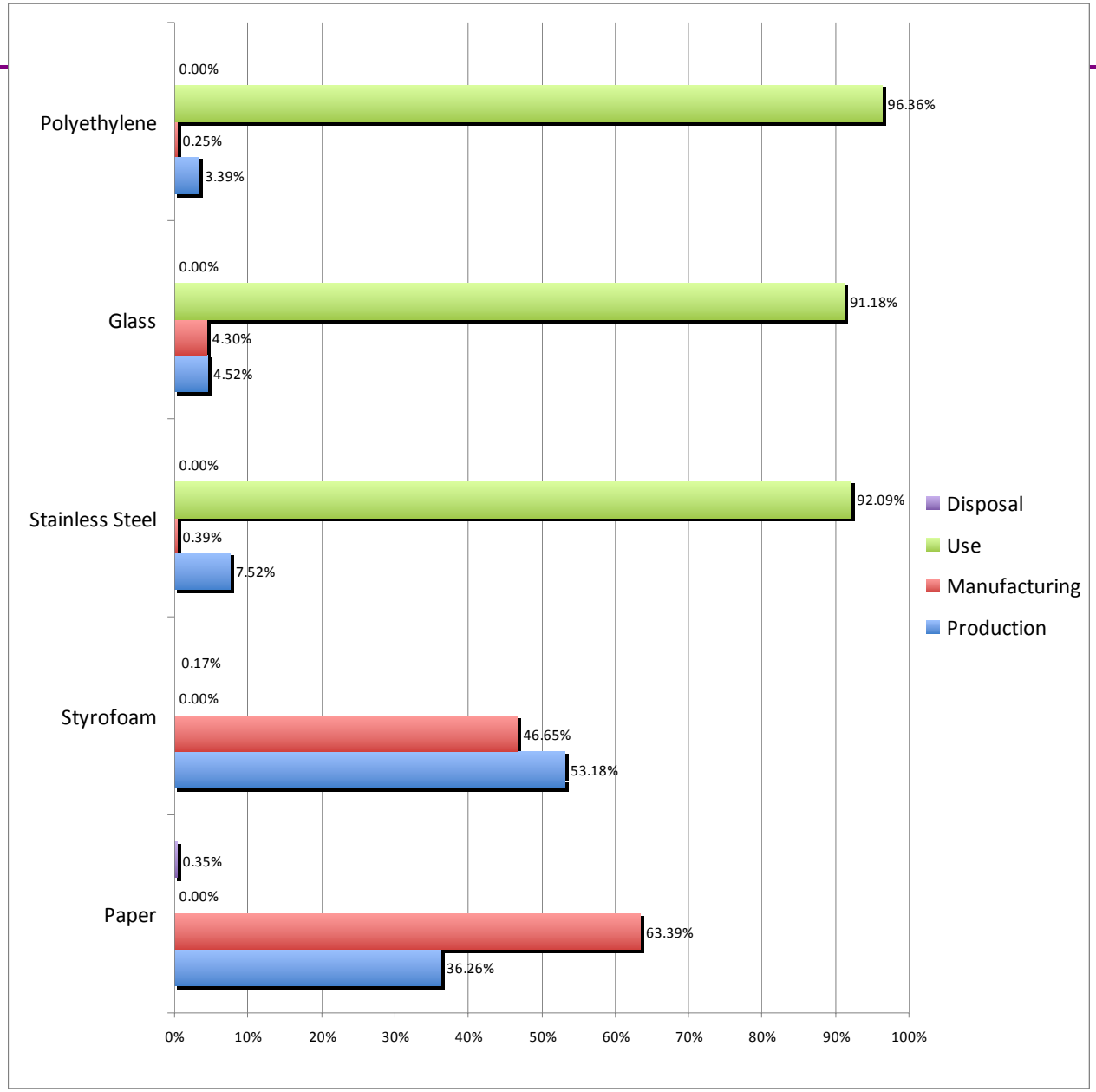
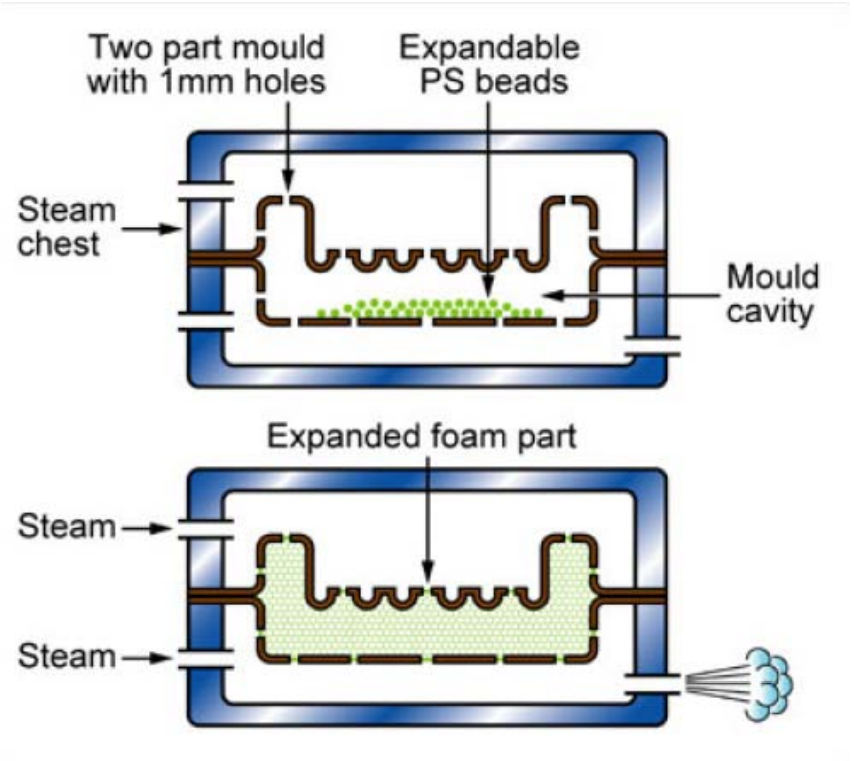


# Processing Methods- Paper

# Processing Method- Polystyrene

- Expanded Foam molding




C9H12

Source: CES Edupack 2005

# Processing- others

# Use

- Average Dishwasher
  - Reusable cups washed after *every* use
  - Energy use: ~80% water, 20% Drying[1]
  - Model uses average household water consumption and drying energy per load[2]
  - 0.06 $gCO_2$ / kJ (electric)[3]
    *assume all energy consumed is electrical*
  - Assume 50 dishes / load

- Average Wash by hand
  - Heat 1/5 gallon of water and air dry

- Break even calculation

$$\#uses_{\text{Break even}} = \frac{E_{reusable}}{E_{disposable} - E_{wash}}$$

1. http://www.bchydro.com/powersmart/elibrary/elibrary705.html
2. http://www.flatheadelectric.com/energy/appliancewattage.htm
3. source: http://cdiac.ornl.gov/pns/faq.html