MSE 395 – Homework 3: Shopping Bag Comparison

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Problem Statement

- Calculate and compare the energy (kJ) and CO_2 emission for shopping bags made of the following materials
  - Paper (25% Recycled/15% Recycled Disposal)
  - HDPE (0% Recycled/3% Recycled Disposal)
  - Reusable Bags
    - Cotton (0% Recycled)
    - Nylon (0% Recycled)
    - PET (100% Recycled)
    - PET (0% Recycled)

Problem Statement

- Calculate the number of reuses for the permanent bags to achieve break-even points as compared to each of the two disposable bags.
- How are results affected by assuming that 25% of the bags are burned to produce electricity with 30% efficiency, rather than land-filled?

Critical Assumptions

- Equivalent Volume
  - Careful bag selection
- Transportation
  - Truck (1,000,000 units per load)
  - 1500km with 100km disposal (if needed)
- Combustion is Ideal
- Negligible ‘Use’ Energy
- When a portion of reusable bags is burned, the balance is still reused

Physical Properties

Bag Type	% Virgin Content (Creation)	% Recycled Content (Creation)	% Recycled Content (Disposal)	% Burned Content (Disposal)	Unit Mass (g/bag)
Plastic Bag (HDPE)					
0% Recycled Creation / 3% Recycled Disposal	100%	0%	3%	0%	12.91
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	100%	0%	3%	25%	12.91
Paper Bag					
25% Recycled Creation / 15% Recycled Disposal	75%	25%	15%	0%	52.42
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	75%	25%	15%	25%	52.42
Reusable Bag (PET)					
0% Recycled Creation / Reused	100%	0%	0%	0%	91.60
0% Recycled Creation / 25% Burned	100%	0%	0%	25%	91.60
100% Recycled Creation / Reused	0%	100%	0%	0%	91.60
100% Recycled Creation / 25% Burned	0%	100%	0%	25%	91.60
Reusable Bag (Nylon)					
0% Recycled Creation / Reused	100%	0%	0%	0%	76.89
0% Recycled Creation / 25% Burned	100%	0%	0%	25%	76.89
Reusable Bag (Cotton)					
0% Recycled Creation / Reused	100%	0%	0%	0%	125.40
0% Recycled Creation / 25% Burned	100%	0%	0%	25%	125.40

Transportation Figures

Bag Type	Transportation			
	Truck Transport (kJ/(g km))	Distance Traveled pre Consumer (km)	Distance Traveled post Consumer (km)	Quantity/Semi-Truck Load
Plastic Bag (HDPE)				
0% Recycled Creation / 3% Recycled Disposal	0.0011	1500.00	100.00	100000.00
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	0.0011	1500.00	100.00	100000.00
Paper Bag				
25% Recycled Creation / 15% Recycled Disposal	0.0011	1500.00	100.00	100000.00
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	0.0011	1500.00	100.00	100000.00
Reusable Bag (PET)				
0% Recycled Creation / Reused	0.0011	1500.00	0.00	100000.00
0% Recycled Creation / 25% Burned	0.0011	1500.00	100.00	100000.00
100% Recycled Creation / Reused	0.0011	1500.00	0.00	100000.00
100% Recycled Creation / 25% Burned	0.0011	1500.00	100.00	100000.00
Reusable Bag (Nylon)				
0% Recycled Creation / Reused	0.0011	1500.00	0.00	100000.00
0% Recycled Creation / 25% Burned	0.0011	1500.00	100.00	100000.00
Reusable Bag (Cotton)				
0% Recycled Creation / Reused	0.0011	1500.00	0.00	100000.00
0% Recycled Creation / 25% Burned	0.0011	1500.00	100.00	100000.00

Lecture Notes
Estimates

Raw Energy Figures

Bag Type	Virgin Embeded (kJ/g)	Recycling Energy (kJ/g)	Recycling Energy Recovery (kJ/g)	Burning Energy Recovery 30% (kJ/bag)
Plastic Bag (HDPE)				
0% Recycled Creation / 3% Recycled Disposal	91.96	38.63	53.33	0.00
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	91.96	38.64	53.32	89.04
Paper Bag				
25% Recycled Creation / 15% Recycled Disposal	33.68	19.98	13.69	0.00
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	33.68	19.98	13.69	118.94
Reusable Bag (PET)				
0% Recycled Creation / Reused	83.75	39.97	43.77	0.00
0% Recycled Creation / 25% Burned	83.75	39.97	43.77	575.33
100% Recycled Creation / Reused	83.75	39.97	43.77	0.00
100% Recycled Creation / 25% Burned	83.75	39.97	43.77	274.61
Reusable Bag (Nylon)				
0% Recycled Creation / Reused	113.41	34.33	79.08	0.00
0% Recycled Creation / 25% Burned	113.41	34.33	79.08	654.02
Reusable Bag (Cotton)				
0% Recycled Creation / Reused	16.89	-	-	0.00
0% Recycled Creation / 25% Burned	16.89	-	-	158.84

Emissions Figures

Bag Type	Virgin Embeded (g/g)	Transport (g/km)	Grid Average Power Production (g/kJ)	Max Theoretical Carbon Content	Theoretical Carbon Content (g)	Equivalent Oxygen Mass in CO2 (g)	Max Theoretical CO2 Content (g/bag)
Plastic Bag (HDPE)							
0% Recycled Creation / 3% Recycled Disposal	3.09	271.35	0.17	86%	11.06	29.50	40.57
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	3.09	271.35	0.17	86%	11.06	29.50	40.57
Paper Bag							
25% Recycled Creation / 15% Recycled Disposal	-0.80	271.35	0.17	44%	23.06	61.51	84.57
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	-0.80	271.35	0.17	44%	23.06	61.51	84.57
Reusable Bag (PET)							
0% Recycled Creation / Reused	2.33	271.35	0.17	63%	57.25	152.67	209.92
0% Recycled Creation / 25% Burned	2.33	271.35	0.17	63%	57.25	152.67	209.92
100% Recycled Creation / Reused	2.33	271.35	0.17	63%	57.25	152.67	209.92
100% Recycled Creation / 25% Burned	2.33	271.35	0.17	63%	57.25	152.67	209.92
Reusable Bag (Nylon)							
0% Recycled Creation / Reused	5.40	271.35	0.17	63%	48.44	129.18	177.62
0% Recycled Creation / 25% Burned	5.40	271.35	0.17	63%	48.44	129.18	177.62
Reusable Bag (Cotton)							
0% Recycled Creation / Reused	0.68	271.35	0.17	45%	56.43	150.48	206.91
0% Recycled Creation / 25% Burned	0.68	271.35	0.17	45%	56.43	150.48	206.91

CES Database
http://www.arb.ca.gov/msprog/hdvip/bip/naftamextrk.pdf
http://gristmill.grist.org/print/2008/1/14/0464/78938?show_comments=no

Energy Contributions

- Embeded Energy + Raw Material
  - Bulk material fabrication
  - Virgin/Recycled energy based on content share
- Manufacturing
  - Cutting and fabrication to produce finished bag
  - Based on bag complexity
- Travel
  - Truck E x Distance x Share of bag in load
- Disposal
  - Transport – Recycling Recovery – Burning Recovery (if any)

Energy Requirements (kJ/bag)

Bag Type	Embeded + Raw Material Manufacturing	Finished Production Manufacturing Energy	Travel	Use	Disposal	Total (kJ/bag)
Plastic Bag (HDPE)						
0% Recycled Creation / 3% Recycled Disposal	1187.20	5.00	21.30	0.00	-19.24	1194.27
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	1187.20	5.00	21.30	0.00	-41.49	1172.01
Paper Bag						
25% Recycled Creation / 15% Recycled Disposal	1585.92	4.00	86.49	0.00	-101.90	1574.51
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	1585.92	4.00	86.49	0.00	-131.64	1544.77
Reusable Bag (PET)						
0% Recycled Creation / Reused	7671.13	20.00	151.14	0.00	0.00	7842.27
0% Recycled Creation / 25% Burned	7671.13	20.00	151.14	0.00	-133.76	7708.51
100% Recycled Creation / Reused	3661.51	20.00	151.14	0.00	0.00	3832.65
100% Recycled Creation / 25% Burned	3661.51	20.00	151.14	0.00	-58.58	3774.07
Reusable Bag (Nylon)						
0% Recycled Creation / Reused	8720.22	20.00	126.87	0.00	0.00	8867.08
0% Recycled Creation / 25% Burned	8720.22	20.00	126.87	0.00	-155.05	8712.04
Reusable Bag (Cotton)						
0% Recycled Creation / Reused	2117.93	20.00	206.91	0.00	0.00	2344.84
0% Recycled Creation / 25% Burned	2117.93	20.00	206.91	0.00	-25.92	2318.92

Emissions Contributions

- ‘Grid’ Emissions Figures
  - Embedded and Manufacturing
- Travel
  - Truck Emissions
- Disposal
  - Transport + Burning (if any)

Emissions (g/bag)

Bag Type	Embeded + Raw Material Manufacturing	Finished Production Manufacturing Energy	Travel	Use	Disposal	Total (g/bag)
Plastic Bag (HDPE)						
0% Recycled Creation / 3% Recycled Disposal	39.83	0.85	4.07	0.00	0.27	45.02
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	39.89	0.85	4.07	0.00	10.41	55.23
Paper Bag						
25% Recycled Creation / 15% Recycled Disposal	-31.45	0.68	4.07	0.00	0.27	-26.43
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	-31.45	0.68	4.07	0.00	21.41	-5.29
Reusable Bag (PET)						
0% Recycled Creation / Reused	213.43	3.40	4.07	0.00	0.00	220.90
0% Recycled Creation / 25% Burned	213.43	3.40	4.07	0.00	52.75	273.65
100% Recycled Creation / Reused	0.00	3.40	4.07	0.00	0.00	7.47
100% Recycled Creation / 25% Burned	0.00	3.40	4.07	0.00	52.75	60.22
Reusable Bag (Nylon)						
0% Recycled Creation / Reused	415.21	3.40	4.07	0.00	0.00	422.68
0% Recycled Creation / 25% Burned	415.21	3.40	4.07	0.00	44.68	467.35
Reusable Bag (Cotton)						
0% Recycled Creation / Reused	84.65	3.40	4.07	0.00	0.00	92.12
0% Recycled Creation / 25% Burned	84.65	3.40	4.07	0.00	52.00	144.11

The Break Down

Bag Type	Total (kJ/bag)	Break Even	Total (g/bag)	Break Even
Plastic Bag (HDPE)				
0% Recycled Creation / 3% Recycled Disposal	1194.27	1.02	45.02	6.03
0% Recycled Creation / 3% Recycled Disposal / 25% Burned	1172.01	1.00	55.23	7.39
Paper Bag				
25% Recycled Creation / 15% Recycled Disposal	1574.51	1.34	-26.43	*
25% Recycled Creation / 15% Recycled Disposal / 25% Burned	1544.77	1.32	-5.29	*
Reusable Bag (PET)				
0% Recycled Creation / Reused	7842.27	6.69	220.90	29.57
0% Recycled Creation / 25% Burned	7708.51	6.58	273.65	36.63
100% Recycled Creation / Reused	3832.65	3.27	7.47	1.00
100% Recycled Creation / 25% Burned	3774.07	3.22	60.22	8.06
Reusable Bag (Nylon)				
0% Recycled Creation / Reused	8867.08	7.57	422.68	56.58
0% Recycled Creation / 25% Burned	8712.04	7.43	467.35	62.56
Reusable Bag (Cotton)				
0% Recycled Creation / Reused	2344.84	2.00	92.12	12.33
0% Recycled Creation / 25% Burned	2318.92	1.98	144.11	19.29

Summary

- For Single Use
  - Plastic – Lowest E
    - Low Mass → Low Embedded Energy Content
  - Paper – Lowest CO_2
- At only 2 uses Cotton bags are competitive
  - PET a near 2nd – Nylon 3rd
- Recycling saves E and CO_2
  - Large Impact
- Burning saves E at expense of CO_2
  - Lesser Impact