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Contents and Sustainability of 'Environmentally Friendly' Cutleries, Paper Plates, and Plastic Cups

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Abstract

To determine the sustainability, and the level of environmental-friendliness of each of these brands of cutlery, plates and cups, we first used the PIXE technology to determine the inorganic contents of the main cutlery pieces and compare this content to that which is found in potatoes or corn, depending on what the brand claimed to use for manufacturing. We also used corn and potato starch to make our own homemade plastics, which we used for further comparison. As an additional side study, we left samples of some of the plastics outside, to determine how much each would degrade under sustained UV/weather exposure.

The companies whose compostable or biodegradable cutleries that we looked at were, World Centric, Greenwave, TarerWare, Green Paper Products, Eco Products, Susty Party and Greenware. World Centric, Green Wave, Green Paper Products all make their plastics from PLA, corn starch, while Taterware make their from potato starch. The Eco Products company had two variations on the cutlery, one white and one cream, the cream is made from "Plant Starch" while the white is "Plant Ware". The difference is not specified. For comparison, we added a plastic spoon made from recycled materials, and a completely normal plastic spoon from Great Value. In addition to this we looked at paper plates from World Centric, Eco Products, Green Paper Products and Susty Party. Finally we also compared a set of clear plastic cups from World Centric and GreenWave (who manufacture through a company called Fabir-Kal).

In addition to the direct comparisons of the contents of the materials we also wanted to determine the energy used to manufacture, transport and dispose of the single-use cutleries to an industrial kitchen for a year. This estimate we then compared to the energy used to wash and maintain an industrial kitchen with common, re-usable cutlery.

All data is in tablular and graphical form in Appendix 1.

Cutlery comparison

Table 1 and Graph 1

The plastic spoons turn out to have very small combined percentage of inorganic elements, the Great Value spoon had less than 0.5%. This makes sense since they are made almost entirely from hydrocarbons. We ran a common plastic spoon, from Great Value, to confirm this, and the total percentage of elements we could detect was around 0.3%.

The most noticable thing is that both the Greenwave, Taterware and Susty Party cutleries have a surprisigly large amount of nickel in them. There is also a trace amount in the Eco Product cutleries. None of the organic source materials, variations of corn samples, the potato, or the corn and potato starches contain even the smallest amount of nickel, so it is likely that this metal was added in processing or creation of the plastic. It's not unlikely to conclude then, that the Greenwave knife could decompose with possible negative effects on the soil.

Another interesting thing is the iron contents in the white Eco Products and Green Paper Products cutleries. Both of these have Iron contents of around 0.2 percent, which is not found in any of the corn materials. Since both are made from PLA, corn plastic, it would be nice to know where in the process of creating plastic it becaume neccesairy to add so much iron. The same is true, to a lesser extent, for the World

Centric, Greenwave and Taterware cutleries. Taterware is supposed to be made from potato starch, but this does not contain any iron either, so unknown origin does not change.

The cobalt content in the White Eco Products cutlery and the Green Paper Product cutlery, is also quite noticable. There is about 0.25 percent in both, which is not a lot, but it is more than can be found in any of the organic materials that they are supposed to be made from.

Titanium is another metal that appears in a surprisingly large concentration in Taterware and World Centric cutleries. But by far, more so in Susty Party. The Susty Party cutlery has a Titanium content of 1.8 percent, which is so large that it had to be removed from the graph, because it overshadowed all the other data. Unlike silicone and calcium however, titanium is quite a heavy metal, and it has no obvious origin. That such a heavy metals have made it into the mixture during processing could be concerning, and there is no obvious explanation.

The largest percentages of inorganic content is the silicon that occurs in the World Centric, Green Paper Products and the Eco Product cutleries. There is between twenty and sixteen percent. This is similar to the silicon content that can be found in dirt, so it is not unlikely that a fair amount of dirt has made it into the mixture during processing. There is also about a percent of silicon in Taterware and about 3.5 in the Susty Party cutleries. These are also probably from dirt, there was probably just less of it.
Dirt could also account for the fairly large calcium amounts in the Greenwave and the Taterware cutleries.

Cutlery Conclusion:

The cutlery type that contains the largest amount of inorganic contents is the Greenwave, with more nickel, phospate and chlorine than any of the others. Taterware is second on this list because of its less, but still large, nickel content and its titanion World Centric is also quite suspicious because it has so much cromium, sulphur and potassium. Susty Party has a disproportunately large titanium content and the still fairly noticable nickel content of around 0.8 percent. The Eco Products knife has anomalous cobalt, iron and sulphur levels,

It seems the cream-colored Eco Products cutlery has the least inorganic content, and it is supposed to be heat resistant, so it is probably the one that would be ideal to use.

Plate comparison

Of the paper plates, World Centric appears to contain the most inorganic components. It has about two percent, while the other plates have between 0.1 and 0.3 percent. World Centric also has a quite noticable amount of calcium, though the Eco Products plate also has a fair amount, both having 1.2 and 0.8 percent respectively. The other two plates both have less than 0.1 percent.

The World Centric plate also has a surprisingly large amount of iron in it, about 0.2 percent. This is strange, because the only other product we looked at that had any real amount of iron were the yellow and green Susty Party plates, and there the iron was probably used to dye the plate. There isn't an obvious reason why there would be so much in a plainly coloured plate.

There was some zinc in both the Susty Party and the World Centric plates, but only World Centric really had a noticable amount. Similarly, World Centric, Green Paper Products and Eco Products all have some cobalt, but World Centric had at least 10 times as much cobalt as any of the others.

In addition to this the World Centric plate contains both nickel and cromium which none of the other plain plates have. Once again, there is a similar amount of nickel in the yellow and green Susty Party plates,

and some of the other dyed plates have a very tiny amount of chromium, but none as much as the World Centric plate.

Plate summary:

The product with the most inorganic components appears to be the World Centric plate, which has higher levels of almost every inorganic element than the other plates. In second is Eco Products, which has such a high calcium content. Both Green Paper Products and Susty Party are pretty even, but since susty party has about 0.2 percent higher inorganic contents than the Green Paper Products, the Green Paper Products undyed plate scores better.

Drinking cup comparison:

There were only two companies who provided drinking cups, World Centric and Fabir-Kal (via GreenWare). As far as we could tell, both of them are actually biodegradable. The ones we put out to exposure of the weather got soft and moldy.

As for the content comparison, Fabir-Kal had 4 times as much silicone as World Centric. Neither had an amount large enough to be anomalous. World centric has about three times as much chlorine as Fabir-Kal and there is some Iron in the World Centric, none in the Fabir-Kal. All of the contents, with the exception of the silicone content in the Fabir-Kal cup, is less than 0.05 percent, so there is very little to be concerned with. Like with some of the cutlerier, maybe the silicone content in the Fabir-Kal cup came from some small amount of dirt mixed into the mulch.

Energy consumption in production (detailed calculations in Appendix 2)

Overal cost and energy expenditure

	Energy per year (Joules)	Cost per year
Dishwasher	3.143E+11	$22400
Green Paper Products	1.0E+12	$254100
GreenWave	3.3E+11	$96800
Susty Party	3.3E+11	$181500
World Centric	3.9E+11	$121000
Eco Products	5.5E+11	$169400
TaterWare	1.2E+12	$81554

These were all very rough energy estimates, but the numbers all show the same thing. The energy costs for simply transporting the necessary mass materials to the factories and the cutleries from the factories to Connecticut College would outweigh the energy costs of using the industrial dishwasher in the main dining hall. This is not taking into account the energy costs for the manufacture and disposal of the plastic cutleries, which could only make the energy costs for using plastic cutleries increase. If this was included, then the estimates could increase as much as 20 percent . The estimates for the amount of money which would be spent on energy and replacement of cutlery is fairly accurate for maintiaining the dishwasher, and it is by far less than the amount of money that would be spent on any of the plastic cutleries.

	WC heat-resistant	Greenwave	TaterWare	GPP - Jaya	Eco Products - White	Eco Products - Cream	Susty Party	Eco Products - Recycled	Great Value Plastic Spoon
Si	19.8 ± 3.2		1.1 ± 0.2	16.7 ± 2.7	16 ± 3		3.5 ± 0.6	0.035 ± 0.006	0.021 ± 0.003
P		0.14 ±				0.06 ±		0.020 ±	0.013 ±

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Appendix

		0.02				0.01		0.003	0.002
S	0.27 ± 0.04	0.06 ± 0.01	0.046 ± 0.008	0.051 ± 0.008	0.21 ± 0.03	0.031 ± 0.005	0.014 ± 0.002	0.016 ± 0.003	0.012 ± 0.002
Cl		0.32 ± 0.05	0.028 ± 0.005	0.09 ± 0.01	0.041 ± 0.007	0.09 ± 0.02	0.012 ± 0.002	0.044 ± 0.007	0.011 ± 0.002
K	0.23 ± 0.04	0.22 ± 0.04	0.031 ± 0.005	0.08 ± 0.01	0.20 ± 0.03	0.08 ± 0.01	0.039 ± 0.006	0.013 ± 0.002	0.16 ± 0.03
Ca	0.117 ± 0.019	4.6 ± 0.7	2.1 ± 0.3	0.29 ± 0.05	0.12 ± 0.02	1.8 ± 0.3	0.718 ± 0.117	0.07 ± 0.01	0.21 ± 0.03
Ti	0.110 ± 0.018		0.25 ± 0.04	0.0025 ± 0.0004	0.012 ± 0.002		1.8 ± .03	1.8 ± .03	
Cr	0.28 ± 0.05		0.006 ± 0.001	0.011 ± 0.002			0.010 ± 0.002		
Fe	0.041 ± 0.007	0.043 ± 0.007	0.029 ± 0.005	0.19 ± 0.03	0.20 ± 0.03	0.0058 ± 0.0009	0.015 ± 0.002	0.0024 ± 0.0004	
Co	0.0025 ± 0.0004			0.024 ± 0.004	0.027 ± 0.004				
Ni		0.50 ± 0.08	0.18 ± 0.03			0.0033 ± 0.0005			
Cu			0.012 ± 0.002	0.007 ± 0.001	0.006 ± 0.001		0.085 ± 0.014	0.006 ± 0.001	0.0041 ± 0.0007
Zn	0.013 ± 0.002						0.0056 ± 0.0009		0.0051 ± 0.0008
Ga							0.009 ± 0.002		

Table 1

Graph1

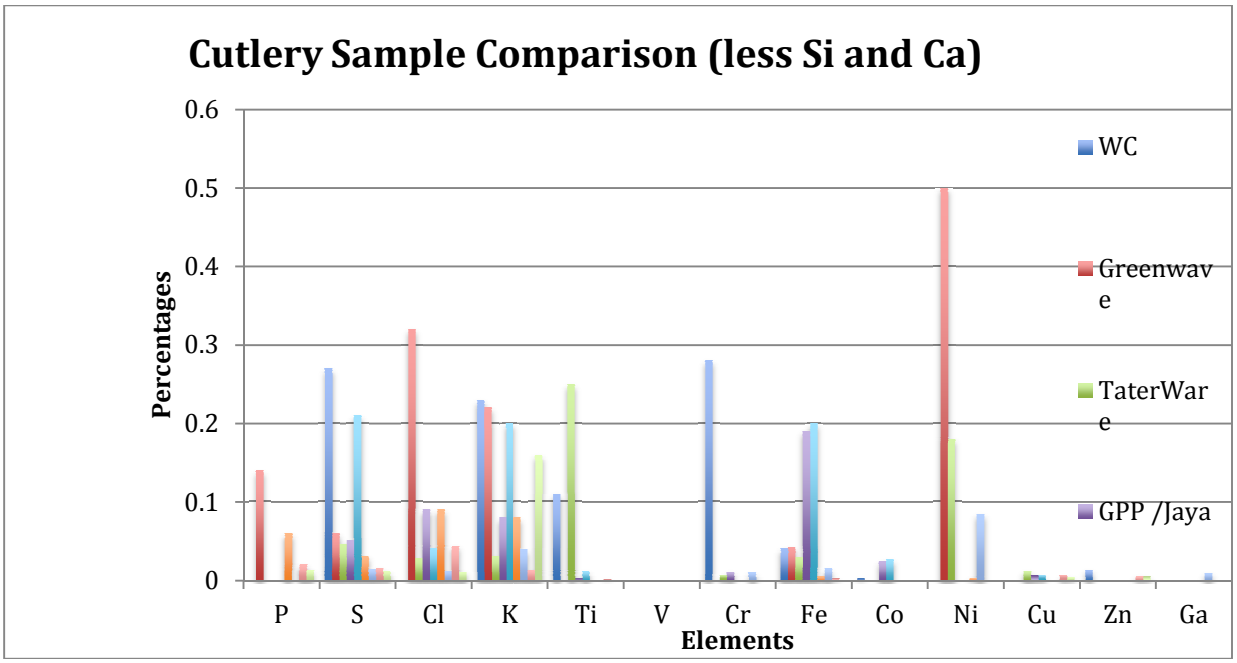

Table 2: Paper Plate – Company Comparison

Element	Eco Products	World Centric	Green Paper Products	Susty Party - white
Si	0.25 ± 0.04	1.9 ± 0.3	0.30 ± 0.05	0.10 ± 0.02
S	0.031 ± 0.005	0.094 ± 0.015	0.026 ± 0.004	0.31 ± 0.05
Cl	0.11 ± 0.02	0.17 ± 0.03	0.057 ± 0.009	0.16 ± 0.03
K	0.08 ± 0.01	0.13 ± 0.02	0.033 ± 0.005	0.159 ± 0.010
Ca	0.8 ± 0.1	1.2 ± 0.2	0.06 ± 0.01	0.07 ± 0.01
Ti	0.0040 ± 0.0007	0.022 ± 0.009	0.0041 ± 0.0007	
Cr		0.022 ± 0.004		
Mn	0.0005 ± 0.0001	0.033 ± 0.005		0.000002 ± 0.0000003
Fe	0.018 ± 0.003	0.19 ± 0.03	0.013 ± 0.002	0.00006 ± 0.00001
Co	0.0016 ± 0.0003	0.058 ± 0.010	0.0015 ± 0.0002	
Ni		0.041 ± 0.007		
Cu	0.0025 ± 0.0004	0.0051 ± 0.0008	0.0044 ± 0.0007	0.00003 ± 0.000005
Zn		0.0014 ± 0.0002		0.000004 ± 0.0000007

Graph 2: Comparison of Paper Plates for different companies

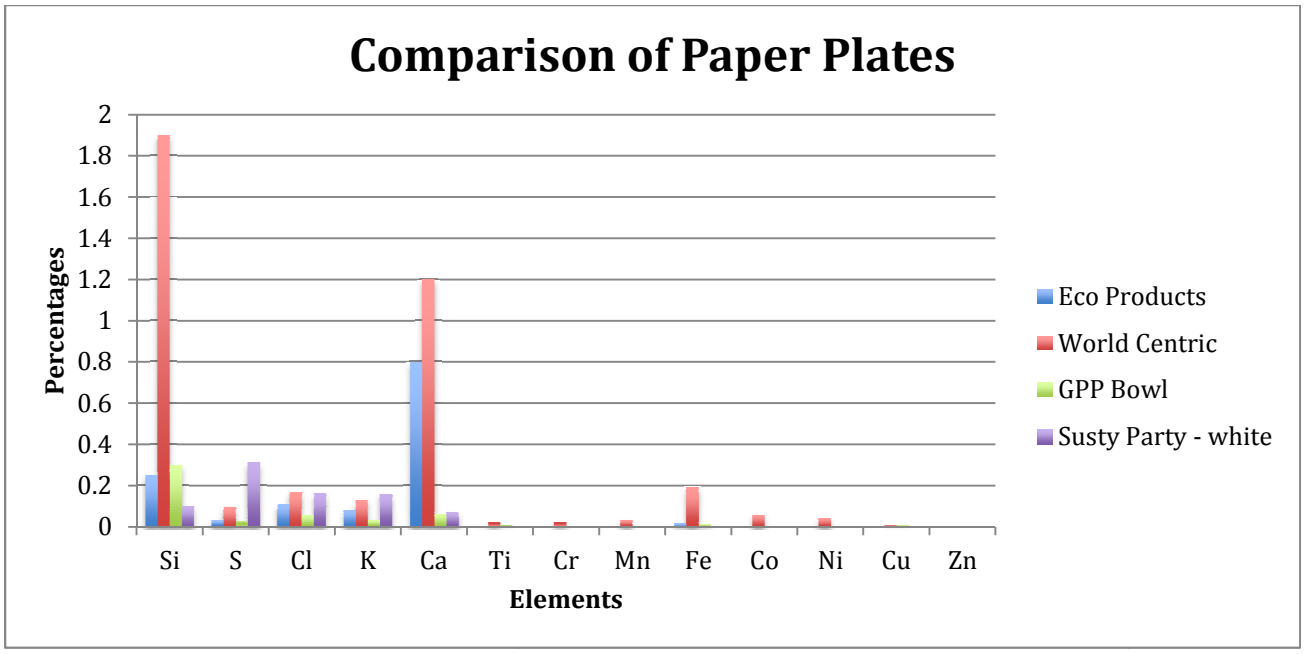

Table 3: Clear Plastic cups – GreenWare (Fabri Kai) and World centric.

Elements	World Centric	GreenWare/Fabir-Kal
Si	0.041 ± 0.007	0.16 ± 0.03
S	0.018 ± 0.003	0.020 ± 0.003
Cl	0.033 ± 0.005	0.010 ± 0.002
K	0.019 ± 0.003	0.010 ± 0.002
Ca	0.0055 ± 0.0009	0.0029 ± 0.0005
Fe	0.0011 ± 0.0002	
Cu	0.0046 ± 0.0007	0.0052 ± 0.0008

Graph 3: Clear Plastic cups – GreenWare (Farbi Kai) and World Centric

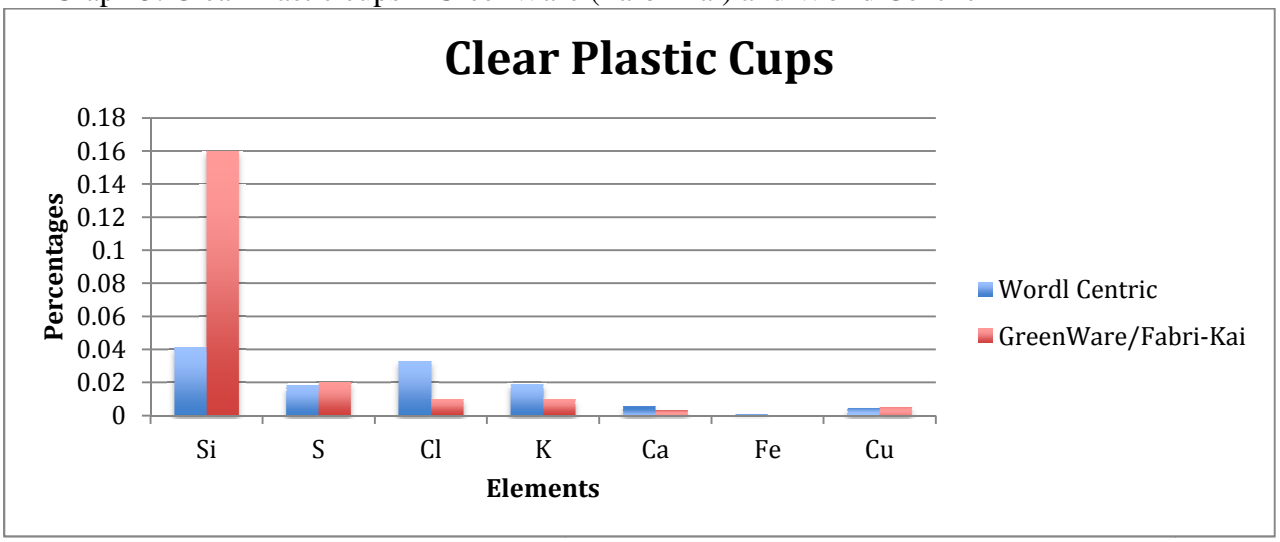

Table of organic materials:

Element	Corn Starch	Corn	Mashed Corn	Corn Cob	Potato	Potato Starch
Al		1.7 ± 0.3		2.0 ± 0.3	3.0 ± 0.5	
Si		0.49 ± 0.08	0.22 ± 0.04	0.32 ± 0.05		0.08 ± 0.01
P	0.10 ± 0.02	0.19 ± 0.03	1.8 ± 0.3	0.15 ± 0.02	0.48 ± 0.08	0.40 ± 0.06
S	0.12 ± 0.02	0.15 ± 0.02	0.6 ± 0.1	0.22 ± 0.04	0.35 ± 0.06	
Cl		1.1 ± 0.2	0.20 ± 0.03	0.20 ± 0.03	0.26 ± 0.04	0.018 ± 0.003
K	0.018 ± 0.003	0.22 ± 0.04	0.18 ± 0.03	0.15 ± 0.02	2.3 ± 0.4	0.23 ± 0.04
Ca	0.022 ± 0.004	0.013 ± 0.002	0.26 ± 0.04	0.52 ± 0.08	0.53 ± 0.09	0.07 ± 0.01
Ti		0.019 ± 0.003	0.019 ± 0.003	0.08 ± 0.01		
Cr		0.047 ± 0.008	0.026 ± 0.004		0.060 ± 0.010	
Mn			0.07 ± 0.01		0.25 ± 0.04	
Fe	0.0004 ± 0.0001				0.11 ± 0.02	0.0010 ± 0.0002
Co				0.019 ± 0.003	0.07 ± 0.01	
Ni						
Cu	0.0048 ± 0.0008	0.0011 ± 0.0002	0.0031 ± 0.0005	0.010 ± 0.002	0.013 ± 0.002	0.0055 ± 0.0009
Zn		0.0035 ± 0.0006	0.010 ± 0.002	0.0019 ± 0.0003	0.0040 ± 0.0007	

Table of Susty Party –dyed plates

	Red	White	Sky Blue	Pink	Yellow	Green	Dark Blue	Black
Al			0.8 ± 0.1		0.60 ± 0.10			
Si	3.5 ± 0.6	0.10 ± 0.02	0.18 ± 0.03	0.11 ± 0.02	0.019 ± 0.003	0.35 ± 0.06	0.39 ± 0.06	0.57 ± 0.09
P			0.31 ± 0.05	0.20 ± 0.03	0.22 ± 0.04	0.38 ± 0.06	0.30 ± 0.05	0.58 ± 0.09
S	0.014 ± 0.002	0.31 ± 0.05	0.32 ± 0.05	0.29 ± 0.05	0.31 ± 0.06	0.45 ± 0.07	0.42 ± 0.07	0.51 ± 0.08
Cl	0.012 ± 0.002	0.16 ± 0.03	0.13 ± 0.02	0.21 ± 0.03	0.17 ± 0.03	0.20 ± 0.03	0.16 ± 0.03	0.44 ± 0.07
K	0.039 ± 0.006	0.159 ± 0.010	0.45 ± 0.07	0.29 ± 0.05	0.30 ± 0.05	0.55 ± 0.09	0.49 ± 0.08	0.80 ± 0.13
Ca	0.718 ± 0.117	0.07 ± 0.01	0.12 ± 0.02	0.08 ± 0.01	0.10 ± 0.02	0.16 ± 0.03	0.15 ± 0.02	0.22 ± 0.04
Ti	1.8 ± .03							
Cr	0.010 ± 0.002					0.0006 ± 0.0001	0.0046 ± 0.0007	0.0048 ± 0.0008
Mn		0.000002 ± 0.0000003		0.0028 ± 0.0005			0.0016 ± 0.0003	0.0097 ± 0.0016
Fe	0.015 ± 0.002	0.00006 ± 0.00001		0.0009 ± 0.0001	0.7 ± 0.1	0.32 ± 0.05	0.0027 ± 0.0004	0.011 ± 0.002
Ni					0.14 ± 0.02	0.061 ± 0.010		
Cu	0.085 ± 0.014	0.00003 ± 0.000005	0.0045 ± 0.0007	0.0034 ± 0.0006	0.0048 ± 0.0008	0.0030 ± 0.0005	0.0016 ± 0.0003	0.0020 ± 0.0003
Zn		0.000004 ± 0.0000007	0.0003 ± 0.00005	0.010 ± 0.002			0.0002 ± 0.00003	
Ga	0.009 ± 0.002					0.0052 ± 0.0008		

Appendix 2 Energy **Calculations**

	Energy per year (Joules)	Money per year
Dishwasher	3.143E+11	$22400
Green Paper Products	1.0E+12	$254100
GreenWave	3.3E+11	$96800
Susty Party	3.3E+11	$181500
World Centric	3.9E+11	$121000
Eco Products	5.5E+11	$169400
TaterWare	1.2E+12	$81554

Constants used repeatedly

Average Weight of Potato*	0.375 kg
Amount of Starch / Potato	0.0825 kg
Total Utensils Needed*	2420000
Starch / Untensil*	28.6 g
Potatoes needed*	807000
Cost of Diesel (National Average)	$1.06
Fuel Efficiency of Truck	3.36 km/L
Fuel Efficiency of Ship	0.003 km/L
Energy / L of Diesel	34.92 MJ/L
Capacity of Ship	216000000 kg
Federal Highway Weight Limit	36287 kg
Weight of Utensil (1000 Count)*	5 kg
Total Weight Needed / Year*	12100 kg
Capacity of Container	21600 kg
Weight of Container	2400 kg
Corn Starch / Corn Cob	20 Tbs
Cutlery / piece of Corn*	10 utensils
Weight of Corn Cob*	0.35 kg
Corn Cobs Needed*	242000
Total Weight of Corn*	84700
Trucks Needed for Corn	5
Containers Needed / Ship	4
Total Weight of Corn on Ship	94300 kg
Weight of Sugarcane Plant	1.4 kg
Volume of Sugarcane Plant	1.93E-3 m^3
# of Sugarcane Plants Needed	345714.3

Notes:
Cost of Diesel comes from averaging current costs of diesel in the following

countries
Germany = $1.68
USA = $0.84
China = $1.04
India = $0.82
* Indicates calculations from our own measurements in the lab or other first hand experiences

Taterware
Raw ingredients come from US, Europe and Asia. Assumed 1/3 of the potatoes come from each location, which means 269000 potatoes per location
US federal law states trucks can only carry a max of 36287 kg, leaving only approximately 20,000 kg left for cargo after subtracting typical weight of truck
Therefore we can fit approximately 53000 potatoes per truck and require 5 trucks per location. We also assumed all of the materials could fit on one cargo ship

Raw Materials (Potatoes)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
KA - CA	2800	14000	
CA - Shanghai			13000
Shanghai -Inland China	2000	10000	
Within Germany	550	2750	
Germany - Hong Kong			23000
Hong Kong - Inland China	2200	11000	
Inland Chinese Starch	1800	9000	

Raw Material Distances:
Truck: 46750 km
Ship: 36000 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
Inland China - Shanghai	2000	2000	
Shanghai - CA			13000
CA - CT	5000	20000	

Final Product Distances:
Truck: 22000 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Raw Material	36000	12000000	336225	18679
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 18970 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	68750	20461

Total Fuel Needed: 39431 L
Total Cost: $41796.86
Energy: 1376931 MJ = 1.2E12 J

Eco Products

Raw Materials (Corn)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
KA - CA	2800	14000	
CA - Shanghai			13000
Shanghai - Inland China	2000	10000	

Raw Material Distances:
Truck: 24000 km
Ship: 13000 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
Inland China - Shanghai	2000	2000	
Shanghai - CA			13000
CA - CT	5000	20000	

Final Product Distances:
Truck: 22000 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Raw Material	13000	4333333	94300	1892
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 2183 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	46000	13690

Total Fuel Needed: 15873 L
Total Cost: $16825.38
Energy: 554285 MJ = 5.5E11 J

Greenware or Natureworks

Raw Materials (Corn)	Distance by Truck (km)	Account for # of Trucks (km)
KA - MO	480	2400

MO - PA	1500	3000

Raw Material Distances:
Truck: 5400 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)
PA - CT	400	1600

Final Product Distances:
Truck: 1600 km

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	7000	2083

Total Fuel Needed: 2083 L
Total Cost: $2208.33
Energy: 72738 MJ = 7.3E10 J

World Centric or NatureWorks

Raw Materials (Corn)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
KA - MO	480	2400	
MO - CA	3250	6500	
CA - China			13000
China Coast - Factory	1800	3600	

Raw Material Distances:
Truck: 12500 km
Ship: 13000 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
China Factory - Coast	1800	1800	13000
China - CA			
CA - CT	5000	20000	

Final Product Distances:
Truck: 21800 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Raw Material	13000	4333333	26580	533
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 824 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	34300	10208

Total Fuel Needed: 11032 L
Total Cost: $11693.92
Energy: 385237 MJ = 3.9E11 J

Susty Party or NatureWorks

Raw Materials (Corn)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
KA - MO	480	2400	
MO - CA	3250	6500	
CA - Taiwan			13000

Raw Material Distances:
Truck: 8900 km
Ship: 13000 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
Taiwan - CA			13000
CA - CT	5000	20000	

Final Product Distances:
Truck: 20000 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Raw Material	13000	4333333	26580	533
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 824 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	28900	8601

Total Fuel Needed: 9425 L
Total Cost: $9989.90
Energy: 329102 MJ = 3.3E11 J

GreenWave

Raw Materials (Corn)	Distance by Truck (km)	Account for # of Trucks (km)
Chengdu - Guang Dong China	1900	9500

Raw Material Distances:
Truck: 9500 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
Guang Dong - Shanghai China	1600	1600	
China - CA			13000
CA - CT	5000	20000	

Final Product Distances:
Truck: 21600 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 291 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	31100	9256

Total Fuel Needed: 9547 L
Total Cost: $10119.82
Energy: 333381 MJ = 3.3E11 J

Green Paper Products

Raw Materials (Sugarcane)	Distance by Truck (km)	Account for # of Trucks (km)
Thailand - Malaysia	3000	75000

Raw Material Distances:
Truck: 75000 km

Final Product (Utensils)	Distance by Truck (km)	Account for # of Trucks (km)	Distance by Ship (km)
Malaysia - Singapore	560	560	
Singapore - CA			13000
CA - CT	5000	20000	

Final Product Distances:
Truck: 20560 km
Ship: 13000 km

Cargo Ship	Total Distance (km)	Fuel Needed (L)	Weight on Ship - With Containers (kg)	Fuel To Transport our Material (L)
Final Product	13000	4333333	14500	291

Total Fuel Needed for Cargo Ship: 291 L

Truck	Total Distance (km)	Fuel Needed (L)
Final & Raw Material	95560	28440

Total Fuel Needed: 28731 L
Total Cost: $3044.86
Energy: 1003287 MJ = 1.0E12 J

Dishwasher

Runs: 100% of time during dinner hours
50% of time during breakfast and lunch hours
343050 meals per semester
Approximately $50/day replacement costs = $11050 / year
453.9L of water used per meal for washing

Time Sheet	Time Slot	Hours	Dishwasher Run	Hours Dishwasher is Run / Week
Breakfast	7:15-10:45	3.5	0.5	10.5
Lunch	10:45-2:00	3.25	0.5	9.75
Light Lunch	2:00-3:30	1.5	0.25	2.625
Dinner	4:30-8:00	3.5	1	24.5
Brunch	9:00-2:00	5		4
Total				51.375
Hours/Year				1,622
Including Breaks Hours Run				1,679

52 kw to heat tank
Therefore, 87308 kwh used per year
Connecticut College pays $0.13/kwh
=$11350.04 per year to use dishwasher
Taking losses into account = **$22400.04 Total Cost**
Energy = 3.143E11 J