GARBAGE RECYCLING DECISION

Date: 03/05/2020
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Subject: Risk analysis report for garbage recycling decision

OBJECTIVE:

To evaluate and recommend the best fuel option among Natural Gas (NG), Barrel Oil (BO) and Wood for the incinerating system of Seymor's recycling center to keep up with the increasing demand.

EXECUTIVE SUMMARY:

Considering the risks involved in investment, operating and material costs for each fuel option, we would recommend using wood. Firstly, the initial investment cost is less for wood. The NPV value for wood is least among the available options. Unlike BO and NG, the operating and material cost for wood is dependent only on the quantity of garbage processed which makes it a feasible long-term solution. Moreover, the officials need not worry about the fluctuations in BO and NG prices.

DISCUSSION:

Software used:

To assess the trends in Barrel oil and Natural gas prices over the years, we used Arena Input analyzer which gives us the best fit distribution for it. The uncertainties in investment, operating and material costs for each fuel option are evaluated using the @RISK software. The net present value is calculated considering a 10% discount rate (could be determined later) using Excel = NPV () function.

Experimental design and analysis:

We use 1000 iterations to narrow down the confidence interval. The below table summarizes the variation in confidence interval with changes in number of iterations.

Number of iterations	Confidence interval (90%)		
	NG	BO	Wood
200	14.1 ± 0.0802	13.82 ± 0.185	13.76 ± 0.0725
500	14 ± 0.0476	13.76 ± 0.118	13.75 ± 0.0483
1000	13.98 ± 0.0312	13.852 ± 0.088	13.71 ± 0.0322
1500	13.98 ± 0.0275	13.84 ± 0.0756	13.70 ± 0.0273

Confidence interval is the measure of error. As we increase the number of iterations, we are decreasing the gap between 'True mean' and simulated mean. Since the simulated mean for wood is least, it is evident that the measure of error for wood is less compared to BO and NG.

Results summary:

	Mean NPV ($ mil)	Std. Dev.	Prediction Interval
NG	14	0.65	[12.99, 15.11]
BO	13.77	1.84	[11.93, 17.38]
Wood	**13.71**	**0.64**	**[12.67, 14.76]**

- The standard deviation is a measure of risk. It tells us about the variation in simulated mean values for each iteration in the model. From the above table, we observe that wood has the least variation.
- A prediction interval is the range of all the possible scenarios thus making it a measure of risk. A narrow prediction interval suggests less risks. From the above table, it is evident that the magnitude of risk is least for wood.
- The simulated mean is the mean of all 1000 possible output values obtained from the simulation.

Shortcomings

- There are no confirmed upper and lower bounds for growth in quantity of garbage processed. We have no information about the variation in growth rates per year.
- The price of wood is dependent on a single factor i.e. quantity of garbage processed, whereas both NG and BO are dependent on 2 factors, quantity of garbage processes and Oil/Gas prices which adds to the uncertainty. Had there been an additional factor affecting wood prices, we would have had a more accurate price comparison and risk analysis.
- The distributions for oil and NG prices are obtained from a limited years data. A bigger sample data could have impacted the results.

APPENDIX

Proposed model:

Year	Quantity of garbage processed (in million tons)
1	1
2	1.1
3	1.21
4	1.331
5	1.4641
6	1.61051
7	1.771561
8	1.9487171
9	2.14358881
10	2.357947691
Mean	1.59374246

year	oil $/barrel
1980	21.59
1981	31.77
1982	28.52
1983	26.19
1984	25.88
1985	24.09
1986	12.51
1987	15.4
1988	12.58
1989	15.86
1990	20.03
1991	16.54
1992	15.99
1993	14.25
1994	13.19
1995	14.62
1996	18.46
1997	17.23
1998	10.87
1999	15.56
2000	26.72
2001	21.84
2002	22.51
2003	27.54
2004	37.66
2005	43.26
Mean	21.17923077
Distribution fit	20.782

year	NG $/10^7 kilocalories
1994	113.8
1995	100.8
1996	129.2
1997	136.2
1998	119
1999	118.7
2000	171
2001	197
2002	154.2
Mean	137.7666667
Distribution	133.66

INVESTMENT COST ($ million)

Year	Natural gas
0	6
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

Year	Barrel oil
0	6
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

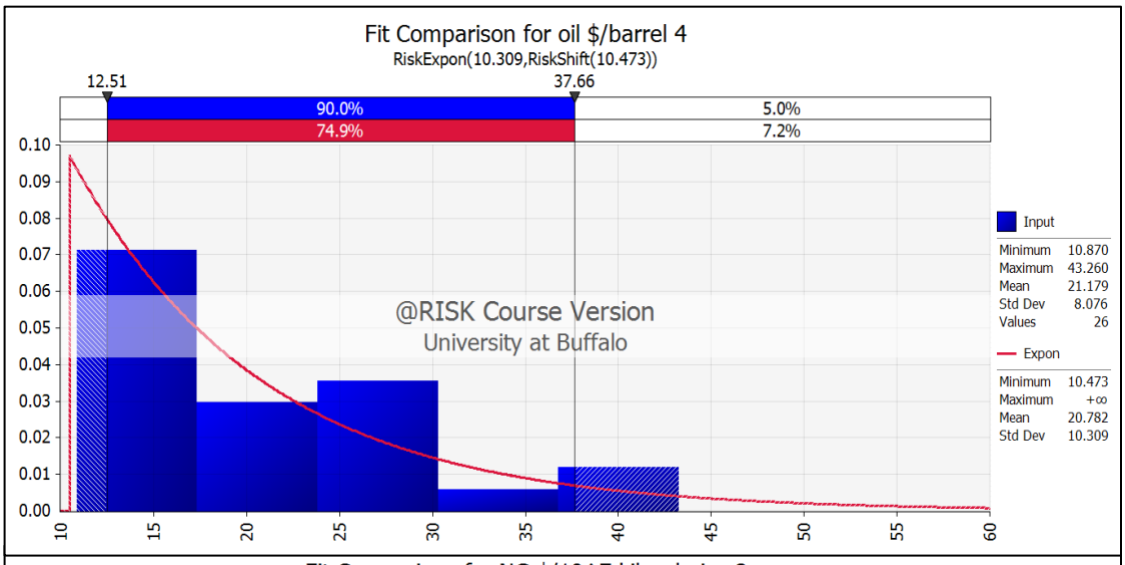
Year	Wood
0	4
1	1.2
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

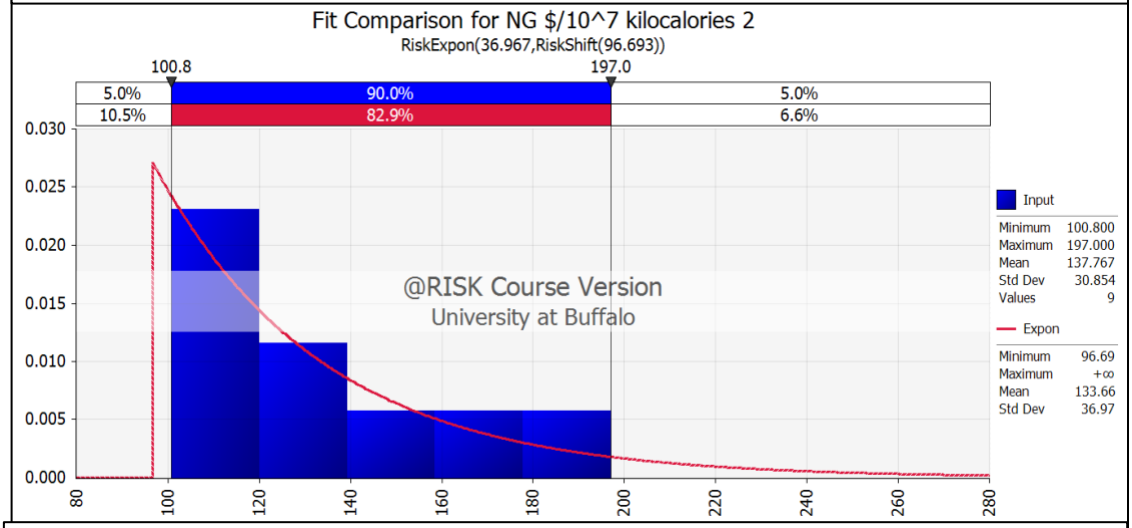
OPERATING COST ($ million)					
Year	Natural gas	Year	Barrel oil	Year	Wood
1	0.5	1	0.6	1	1
2	0.55	2	0.66	2	1.1
3	0.605	3	0.726	3	1.21
4	0.6655	4	0.7986	4	1.331
5	0.73205	5	0.87846	5	1.4641
6	0.805255	6	0.966306	6	1.61051
7	0.8857805	7	1.0629366	7	1.771561
8	0.97435855	8	1.16923026	8	1.9487171
9	1.071794405	9	1.286153286	9	2.14358881
10	1.178973846	10	1.414768615	10	2.357947691

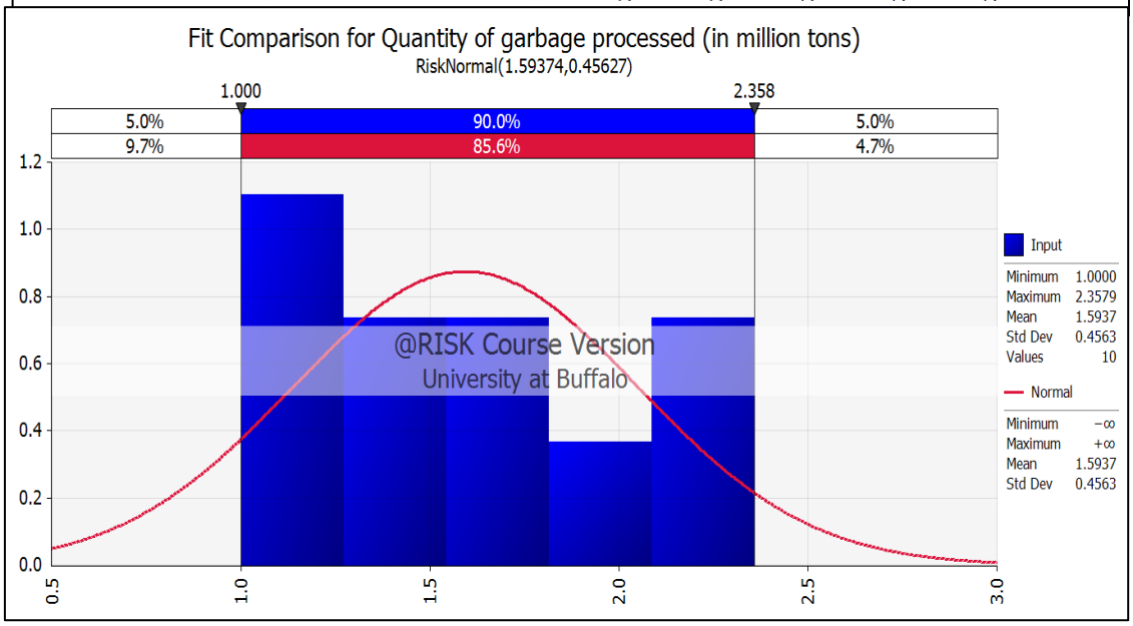
OPERATING COST ($ million)					
Year	Natural gas	Year	Barrel oil	Year	Wood
1	0.5	1	0.6	1	1
2	0.55	2	0.66	2	1.1
3	0.605	3	0.726	3	1.21
4	0.6655	4	0.7986	4	1.331
5	0.73205	5	0.87846	5	1.4641
6	0.805255	6	0.966306	6	1.61051
7	0.8857805	7	1.0629366	7	1.771561
8	0.97435855	8	1.16923026	8	1.9487171
9	1.071794405	9	1.286153286	9	2.14358881
10	1.178973846	10	1.414768615	10	2.357947691

Input modelling:

- We use @Risk's input analyzer to find the best fit distribution for our given data.
- Arena's input analyzer gives us Weibull/Beta distributions as the best fit. However, since these distributions are too flexible, they usually come out to be the best fit for any kind of data. This makes them less reliable to capture the uncertainties.
- The next best fit distribution obtained was exponential distribution.
- For the investment cost of wood, we use Triangle distribution since we have an idea about the most likely scenario and upper bound. We choose as reasonable lower bound of $ 0.6 mil. The function used is: = RiskTriang(0.6,1,2)
- For the growth rate of garbage processed, we use normal distribution since the average growth rate is known to us. We truncate the lower bound to 0, since the growth can never be negative. A standard deviation of 0.05 is used since we have an estimate of the lower and upper bounds of growth rate.


Fit Comparison for oil $/barrel 4
RiskExpon(10.309,RiskShift(10.473))
12.51
37.66
90.0%
5.0%
74.9%
7.2%
@RISK Course Version
University at Buffalo
Input
Minimum 10.870
Maximum 43.260
Mean 21.179
Std Dev 8.076
Values 26
Expon
Minimum 10.473
Maximum +∞
Mean 20.782
Std Dev 10.309


Fit Comparison for NG $/10^7 kilocalories 2
RiskExpon(36.967,RiskShift(96.693))
100.8
197.0
5.0%
90.0%
5.0%
10.5%
82.9%
6.6%
@RISK Course Version
University at Buffalo
Input
Minimum 100.800
Maximum 197.000
Mean 137.767
Std Dev 30.854
Values 9
Expon
Minimum 96.69
Maximum +∞
Mean 133.66
Std Dev 36.97


Fit Comparison for Quantity of garbage processed (in million tons)
RiskNormal(1.59374,0.45627)
1.000
2.358
5.0%
90.0%
5.0%
9.7%
85.6%
4.7%
@RISK Course Version
University at Buffalo
Input
Minimum 1.0000
Maximum 2.3579
Mean 1.5937
Std Dev 0.4563
Values 10
Normal
Minimum −∞
Maximum +∞
Mean 1.5937
Std Dev 0.4563

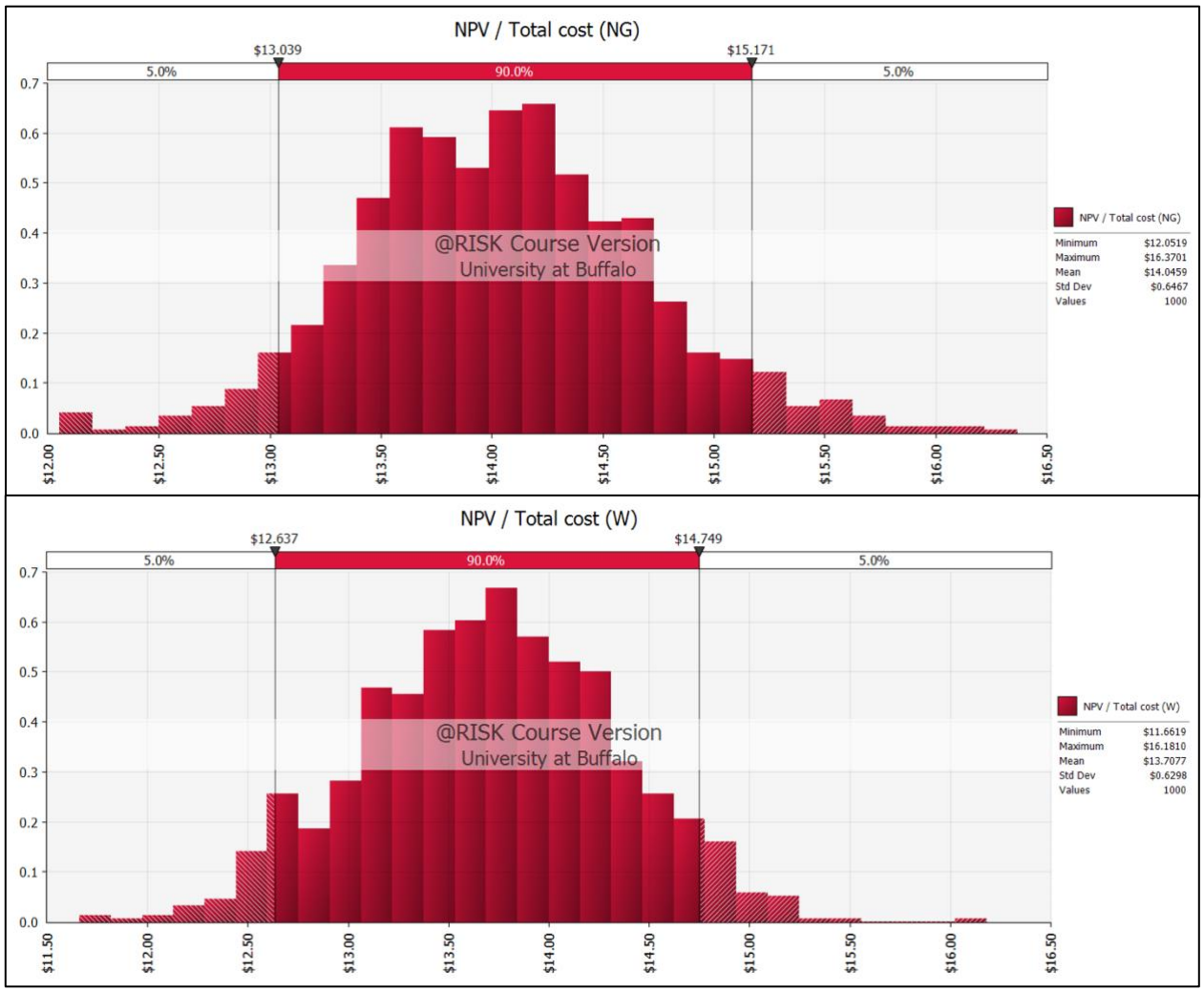
Simulation settings:

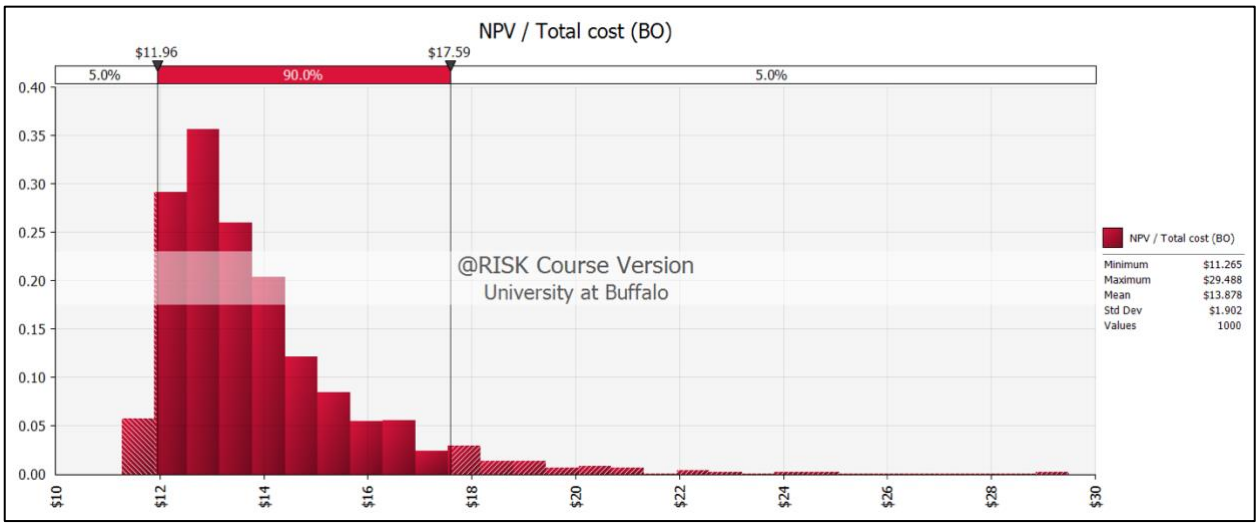
1. Number of iterations:
   - We set the iterations to 1000 per simulation. We arrived at this number by studying the confidence interval at different number of iterations. Simultaneously, we also use the manual approach by using the formula:
   - C.I. = mean +/- 1.64 * Std.Dev. * $\sqrt{(1/n)}$, where n is the number of iterations.
   - We set a 90% confidence interval for our analysis.

2. Sampling type: Monte Carlo

3. Initial seed: Choose randomly

Output analysis:

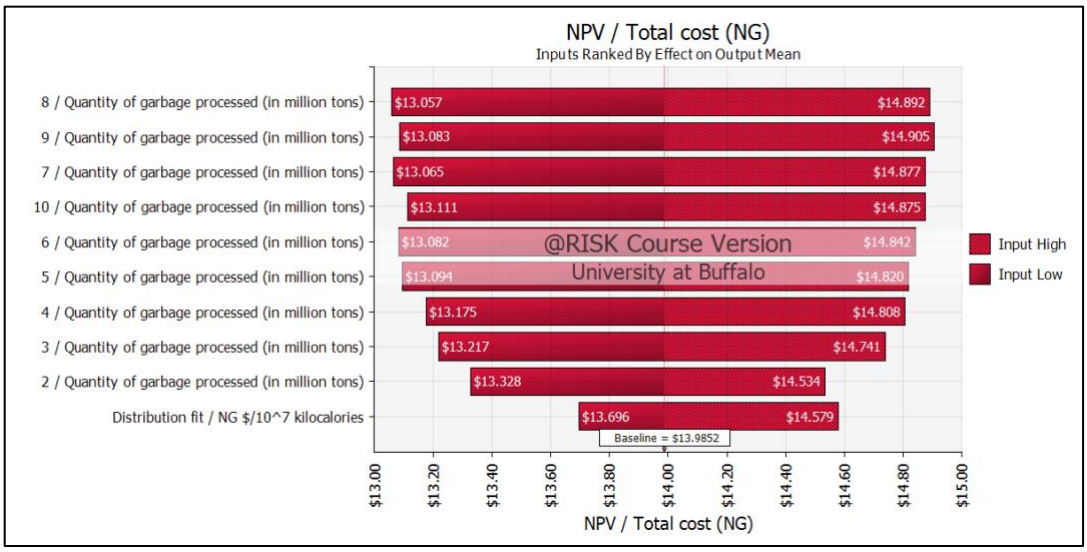


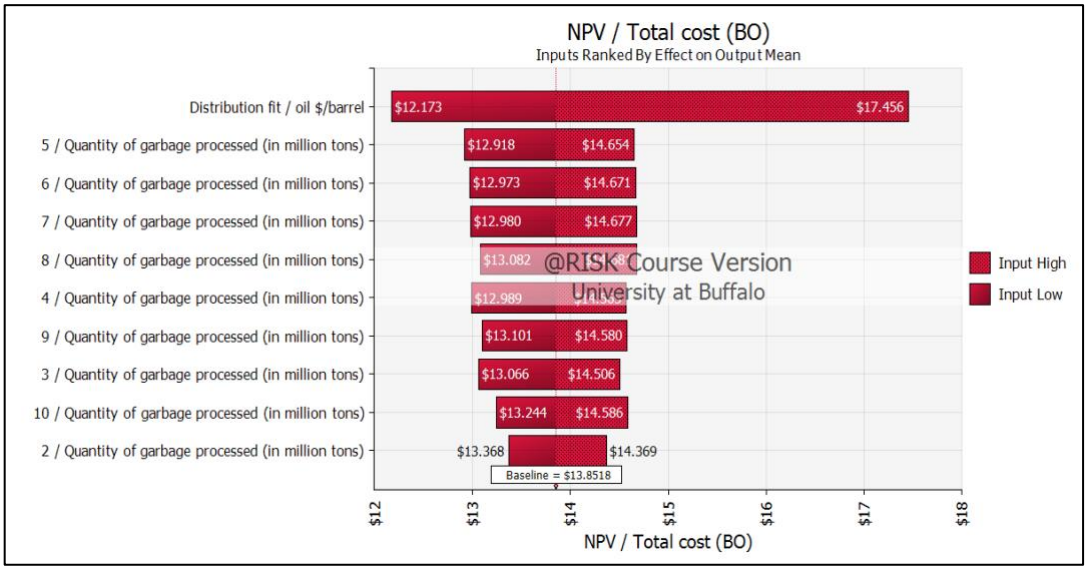


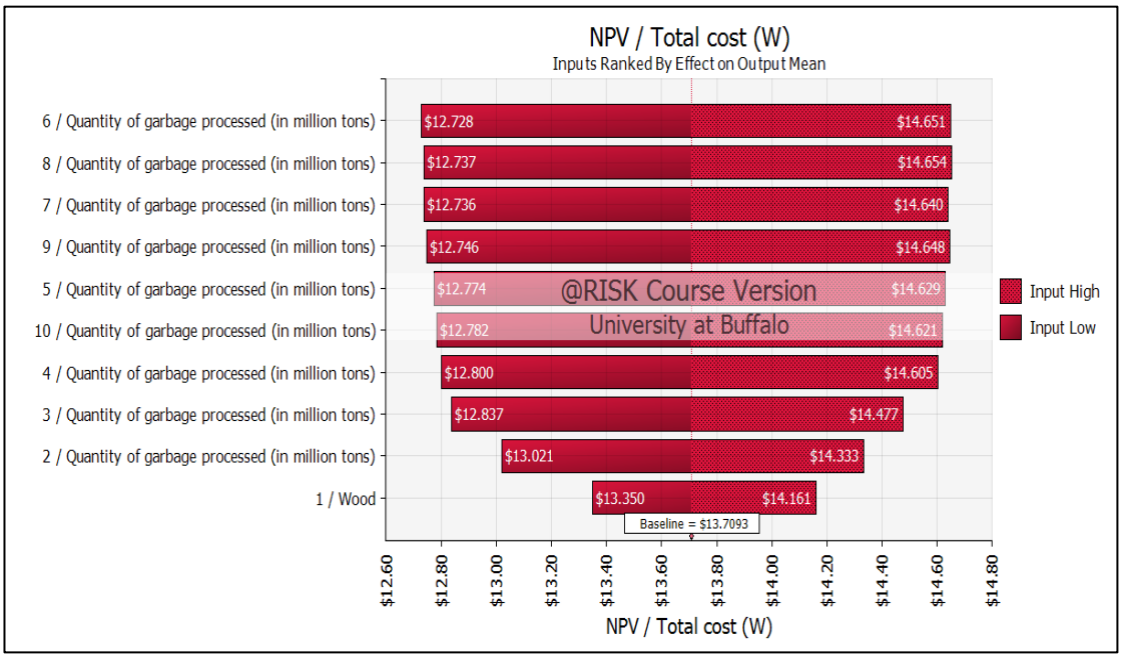
- Histograms are a useful tool to understand the distribution of our data. In this case, it helps us compare the fuel types using various parameters like prediction intervals, standard deviation, mean value, etc.
- The maximum and minimum values obtained from histogram are not the worst-case scenarios. They are the min/max values for our particular simulation.
- A lower standard deviation means lower error. It is used as a measure of error. Since the value is least for wood, it is considered to be the better option.

Sensitivity analysis:

- The sensitivity analysis tells us about the impact of our input uncertainties on the output.
- It helps in assessing the riskiness of a chosen strategy.
- In our case, it is evident from the tornado graphs that wood cost is impacted more by the processed garbage quantity, Natural gas is impacted more by the processed garbage quantity along with the natural gas prices and Barrel oil is highly impacted by the oil prices along with garbage quantity.
- If we could incorporate uncertainties related to quantity of garbage processed properly, we could further improve our model.


NPV / Total cost (NG)
Inputs Ranked By Effect on Output Mean
8 / Quantity of garbage processed (in million tons)
9 / Quantity of garbage processed (in million tons)
7 / Quantity of garbage processed (in million tons)
10 / Quantity of garbage processed (in million tons)
6 / Quantity of garbage processed (in million tons)
5 / Quantity of garbage processed (in million tons)
4 / Quantity of garbage processed (in million tons)
3 / Quantity of garbage processed (in million tons)
2 / Quantity of garbage processed (in million tons)
Distribution fit / NG $/10^7 kilocalories
$13.057
$14.892
$13.083
$14.905
$13.065
$14.877
$13.111
$14.875
$13.082
$14.842
$13.094
$14.820
$13.175
$14.808
$13.217
$14.741
$13.328
$14.534
$13.696
$14.579
Baseline = $13.9852
@RISK Course Version
University at Buffalo
Input High
Input Low
$13.00
$13.20
$13.40
$13.60
$13.80
$14.00
$14.20
$14.40
$14.60
$14.80
$15.00
NPV / Total cost (NG)


NPV / Total cost (BO)
Inputs Ranked By Effect on Output Mean
Distribution fit / oil $/barrel
5 / Quantity of garbage processed (in million tons)
6 / Quantity of garbage processed (in million tons)
7 / Quantity of garbage processed (in million tons)
8 / Quantity of garbage processed (in million tons)
4 / Quantity of garbage processed (in million tons)
9 / Quantity of garbage processed (in million tons)
3 / Quantity of garbage processed (in million tons)
10 / Quantity of garbage processed (in million tons)
2 / Quantity of garbage processed (in million tons)
$12.173
$17.456
$12.918
$14.654
$12.973
$14.671
$12.980
$14.677
$13.082
$12.989
$13.101
$14.580
$13.066
$14.506
$13.244
$14.586
$13.368
$14.369
Baseline = $13.8518
@RISK Course Version
University at Buffalo
Input High
Input Low
$12
$13
$14
$15
$16
$17
$18
NPV / Total cost (BO)


NPV / Total cost (W)
Inputs Ranked By Effect on Output Mean
6 / Quantity of garbage processed (in million tons)
8 / Quantity of garbage processed (in million tons)
7 / Quantity of garbage processed (in million tons)
9 / Quantity of garbage processed (in million tons)
5 / Quantity of garbage processed (in million tons)
10 / Quantity of garbage processed (in million tons)
4 / Quantity of garbage processed (in million tons)
3 / Quantity of garbage processed (in million tons)
2 / Quantity of garbage processed (in million tons)
1 / Wood
$12.728
$14.651
$12.737
$14.654
$12.736
$14.640
$12.746
$14.648
$12.774
$14.629
$12.782
$14.621
$12.800
$14.605
$12.837
$14.477
$13.021
$14.333
$13.350
$14.161
Baseline = $13.7093
@RISK Course Version
University at Buffalo
Input High
Input Low
$12.60
$12.80
$13.00
$13.20
$13.40
$13.60
$13.80
$14.00
$14.20
$14.40
$14.60
$14.80
NPV / Total cost (W)