CUMMINS INC.

Landfill Gas Utilization and Feasibility Study

A Community Involvement 6S Project

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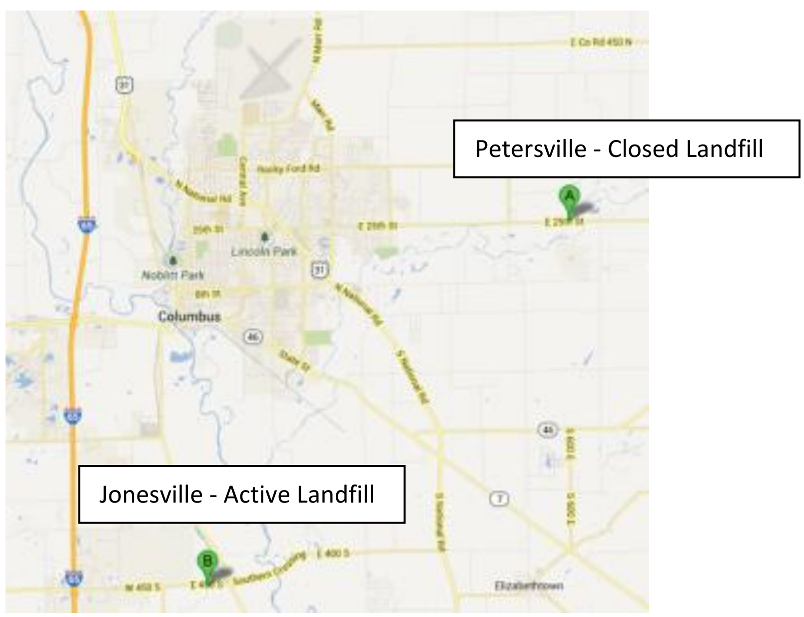

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Executive Summary

The purpose of this report is to document the landfill study efforts of the Cummins State Street Community Involvement Team (CSS CIT) and Bartholomew County Solid Waste Management District (BCSWMD). The team conducted a Six Sigma project to understand the needs, potential uses and feasibility of using the landfill gas from the Petersville and Jonesville landfill sites.

The first phase in our process was conducting a Voice of the Customer (VOC) and visits to the landfills to more completely understand the perspectives of the customers. In addition, other landfill applications were benchmarked through technical interviews and reviews of landfill application materials. Through the team's efforts five landfills were researched, six landfill specialists were interviewed, and more than 20 landfill project articles were reviewed.

The next phase in was concept design. The concept design phase was subdivided into a marketing phase, which was comprised of community outreach through a variety of communication channels, including newspaper, internet, Cummins intranet, radio broadcast and word of mouth. These outreach channels all directed the public to the Landfill Utilization booklet on the Bartholomew County Solid Waste Management District's website for more information, which ensured consistency in messaging. . After this, an internal Cummins brainstorming session was conducted by the Six Sigma team to gather ideas for the different landfill sites. The brainstorming session generated concepts for each of the landfill sites. Once the concepts were drafted, important information including average costs and revenue were investigated and added to each concept.

After the concept design phase, the feasibility phase of the project began. The first aspect of the feasibility portion was developing metrics to rank the projects against each other. This was performed by using a Quality Function Deployment (QFD) table. Subsequently, a financial simulation study was conducted for the Jonesville site to derive a simple payback period, annual revenue, and Net Present Value (NPV) for each project. The projects were then ranked against each other using a comparison table and a Cause & Effect ranking matrix.

In conclusion, the ranking matrix helped the team to determine that the Jonesville site will have the most benefit from a direct gas application. On the other hand, the Petersville site had mixed results because the best application was not readily identifiable; however, this means that the possibility of having a community project is still feasible if others are willing to invest time, energy, and money.

Introduction

In 2012, the Cummins State Street Community Involvement Team (CSS CIT) began an effort to enhance the relationships with designated community partners. The Cummins team visited the Bartholomew County Solid Waste Management District (BCSWMD) on July 20th, 2012 to explore the recycling center and brainstorm activities that could have a positive long term impact for BCSWMD. After the visit, the Cummins team decided to conduct a Community Involvement Six Sigma (CISS) project consisting of utilization and feasibility studies of the Petersville and Jonesville landfill sites. This report will document the efforts of the Six Sigma team, communicate the outcome of the project and present a sample business case for the landfills.

Problem Statement

After the initial visit to BCSWMD's recycling center, the CSS CIT group met to discuss potential projects on July 27th, 2012. The landfill project was defined as:

"Prepare a feasibility study for the utilization of landfill gas at the Bartholomew County landfills. Explore both medium BTU pipeline projects and electrical generation for use onsite. Present findings to the Solid Waste Board of Directors."

This problem statement was scoped by the CISS team using the tools from 6S and is discussed in the section "Project Scope and Timeline".

Project Scope and Timeline

The 6S contract form was used to translate the original problem statement by dividing it into sub-sections: project name, team members, objective, deliverables, constraints, scope, assumptions, and critical functional responses. The project name was titled, "CISS – Feasibility Study for utilization of landfill gas at Bartholomew County landfills," and the objective was changed to "Determine different methods of using the natural gas at the Bartholomew County landfill sites and identify which is the best way to use the natural gas for Bartholomew County Solid Waste Management District." After the objective was defined, the deliverables were broken down into 6S tools with the high-level deliverable being "ranked utilization concepts in terms of feasibility and determining future phases of the project." The specific tools are explained in Table 1.

Table 1 Specific Tools

Deliverable	Specific Tool(s)
Project Plan	Responsibility Matrix (RACI)
Determination of Voice of Customer (VOC)	Customer Selection Matrix, Profitability Correlation, VOC, Discussion Guide, Translation
Determination of Options for Utilizing Landfill Gas	Concept Generation
Compare key quantifiable metrics between utilization concepts	Metric Generation, QFD HOQ, and Comparison
Rank projects and identify risks to make final project selection for Bartholomew County landfill site easier	Cause & Effect Matrix, Architecture P-diagram
End deliverable of determining future phases of project	Close-out presentation/detailed report delivered to Bartholomew county.

In addition to scope and tool definition, the 6S charter also describes the constraints of the project by defining what is in and out of scope. The Petersville and Jonesville landfills were in scope for the study; however, there was no proof of concept or capital investment expenditure required. Furthermore, landfills outside of Bartholomew County's jurisdiction were not included in the study. Last but not least the team members were selected. The final team members elected to the team are pictured below in Figure 1.

Figure 1 6S Core Team

In order to manage the project and ensure the right tools were used, a Gantt chart was developed with the team. The final iteration of the Gant chart is shown in Figure 1.

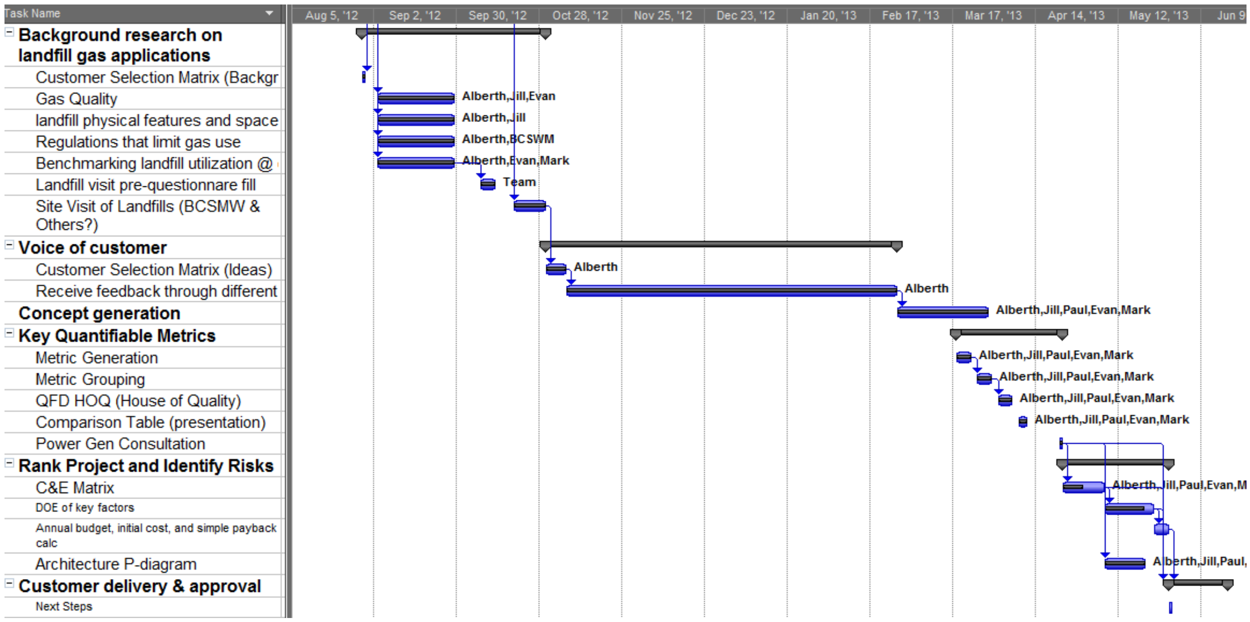


Figure 2 Gantt chart

Voice of Customer

The voice of customer method traditionally requires a Customer Selection Matrix and Discussion Guide followed by a KJ. For this particular project, the structure of the tools was modified because there is one customer, BCSWMD. Instead of using the Customer Selection Matrix to understand who the team wanted to survey for customer input, the matrix was used to identify potential points of contact at different phases of the project. The final matrix is shown in Table 2 “Customer Selection Matrix.”

Table 2 Customer Selection Matrix

	Customer Description		
	End User	Beneficiary	Thoughts Supplier
People	1. BCSMWD Landfills		1. Mark Rosswurm 2. Jason Abon 3. Jim Murray
Businesses	1. Businesses near walesboro 2. Fire house at Jonesville 3. Duke Energy 4. Glass blowing/horticulture	1. BCSMWD 2. City of Columbus 3. End user	1. Cummins Inc. 2. BCSMWD 3. The Republic 4. Radio 5. Other landfills 6. SCS Engineers
Groups	1. Cummins CIT Teams 2. Surrounding Community 3. Government groups		1. CSS CIT 2. Cummins Employees 3. ESB

Once the Customer Selection Matrix was completed, the team began to investigate the current state of the Petersville and Jonesville landfills. BCSWMD provided information in order to begin the initial background investigation of the two sites including preliminary requirements shown in Figure 3. The information from BCSWMD included a preliminary case study of the two landfill sites, an air regulation report conducted by SCS engineering, and literature of successful landfill utilization techniques. The ensuing paragraph will explain the information obtained from the different materials provided by BCSWMD.

The study from the EPA gave the 6S team some of the landfills' characteristics such as waste-in-place at closure, average waste acceptance, and projected landfill gas flow rate to 2033. The characteristics for the individual sites are highlighted in Table 3 Landfill Characteristics and Figures 3 and 4.

VOC Review - All Relevant Details to KAF Project	Translation	Metric for Landfill Utilization Study
Landfill project with low upfront cost	Minimal dollar figures needed from customer	Dollar amount for initial investment of project (before and after funding)
No Bio Reactor Landfill	Wet Landfills are not acceptable	Wet Landfill ideas will not be used
Plumbing in new landfill would be additional cost	Plumbing cost & time will need to be included for concept selection	Team will agree to assume (XX) as dollar amount for plumbing and installation
Old Landfill concepts will have limited methane projected for near future	Old Landfill concepts will have limited methane projected for near future	Old Landfill has about 15-20 years of available gas and is able to get 7 cfm for air handling with current plumbing
New Landfill will be ready to use within 4 years	Project implementation timeline	Project should be feasible to set up and start in 4 years
Soil restriction on Old Landfill, not on new	Project at old landfill should not require extensive use of sand capping	The less sand a project will require, the better rating
New Landfill has considerable Wetlands fauna (vultures, frogs, turtles)	Project should keep wetlands in mind	Concept will not reside on wetland area
Comply with government regulations	Must comply with EPA regulations	Must meet title 2 Air permit & leechate collection policies

Figure 3 BCSWMD VOC

Table 3 Landfill Characteristics

Characteristic	Petersville	Jonesville
Project Type	Direct Use	Direct Use
Waste – In – Place at Closure (tons)	1,886,567	3,256,679
Average Depth of Landfill Waste (ft)	50	40

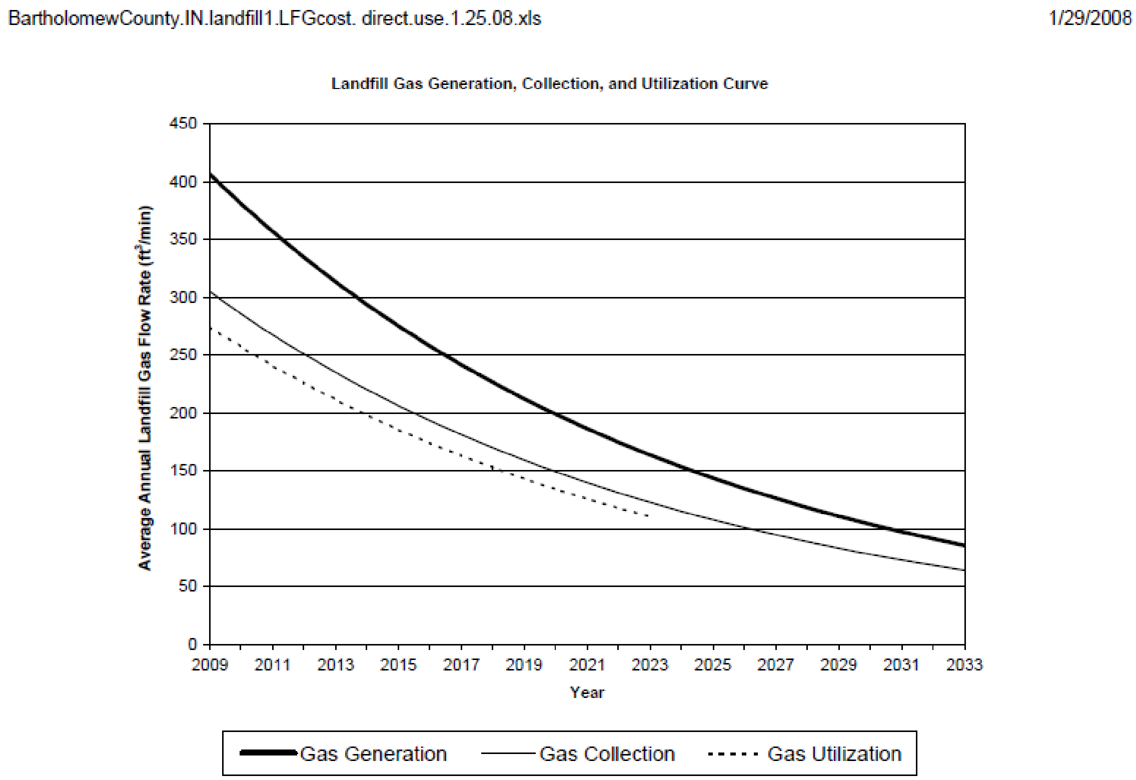


Figure 4 Petersville Predicted Gas Availability

The waste in place at closure from Table 3 and the graph generation prediction from Figure 3 allowed the group to draw the conclusion that the Petersville site is a small landfill with gas generation past the half life of max production. In other words, the site would be ideal for a cottage scale project such as the North Carolina Energy Exchange Project venture that "supports entrepreneurs in starting, managing, and operating new businesses in crafts (glass and clay) and apprenticing in horticulture." More specifically, the site contains four greenhouses that helps propagate native ornamentals from seed, a craft studio for pottery and glass blowing, and an outreach and tourist center to showcase the project's success. Further information can be found in the Benchmarking Current Strategies section and the Appendix.

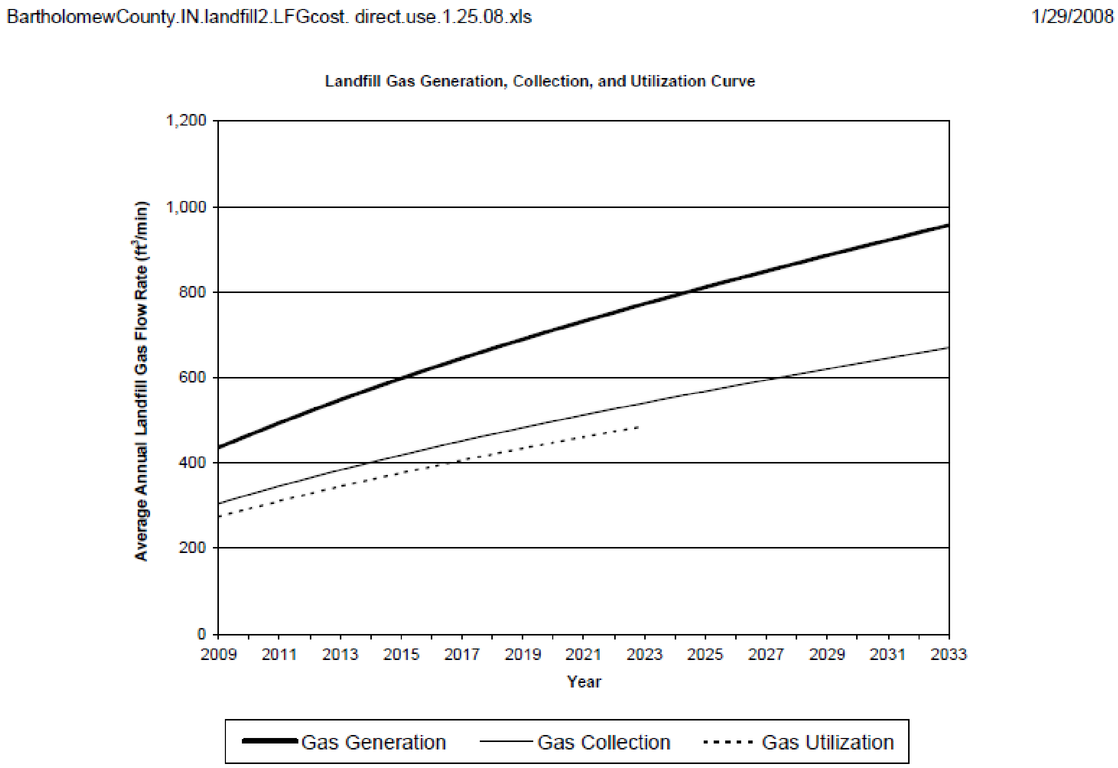


Figure 5 Jonesville Predicted Gas Availability

The waste in place at closure from Table 3 and the graph generation prediction from Figure 5 allowed the group to draw the conclusion that the Jonesville site is a medium sized landfill with the potential for gas generation above 800 CFM. Because of the higher gas availability prediction, the project types for the landfill would be of larger scale such as power generation or direct piping of the gas.

In addition to the EPA study, SCS engineer released a report to BCSWMD to certify that the landfill met the New Source Performance Standards (NSPS) regulations. Table 4 shows the lab analysis that SCR conducted on the different flaring locations of the Petersville site. The specific locations of the sites can be found in the original report, which is obtainable at the discretion of BCSWMD. In addition, the analysis results are reported without any correction for the presence of water.

Table 4 SCS Permanent Gases Analysis

Sampled ID/Gas (Concentration in %v)	Bart 1-5	Bart 6-10	Bart 11-15	Bart 16-20
Methane	58.7	57.7	50.5	50.4
Carbon Dioxide	36.5	38.2	44.5	43.4
Nitrogen	2.38	1.56	1.93	1.26
Oxygen	0.64	0.45	0.48	0.42

The report led the group to conclude that the landfill follows the theoretical composition of 50% methane, 40% carbon dioxide, 2% nitrogen, .5% O2, and the remaining percentage is a mix of other gasses that varies from landfill to landfill. In order to get a detailed report of all constituents, it was recommended that BCSWMD conduct a more precise gas composition measurement.

After reading additional background studies on landfill application usage from landfill gas basics to an evaluation of fuel treatment options of landfill fuels, the team decided to conduct a site visit at the Petersville and Jonesville landfills. The full report citation is in the Appendix for readers who wish to read them.

Site Visits

On October 9, 2012, the CSS CIT team visited the Petersville and Jonesville landfill sites to survey and document any additional information that would be useful for the project. Before making the visit, the team reviewed Figures 5 and 6 to understand the layout of each individual site. The following section summarizes findings from the landfill site visits.

For the Petersville site, usage of the McNealy farm area would be an entitlement to the end landfill gas usage. The area is currently leased by BCSWMD to McNealy farms, but they only use a small portion of the total land area; therefore, the possibility exists to use the remaining land area in a cottage scale landfill gas application. Another key feature of the site is that the site is completely capped and currently has a passive flaring system. There are three solar flares connected to the on-site wells which have PVC manifolds that connect the HDPE passive above-ground vents. Solar panels are used to power the spark plug that flares the gas and a filter and flame arrestor is used for safety purposes. The passive flaring system alleviates foul odors from landfill gas that seeps into the air from the soil. Maintenance costs of the system are about $100.00 per year and replacement units cost about $2,000.00. A picture of the unit is shown in Figure 7.

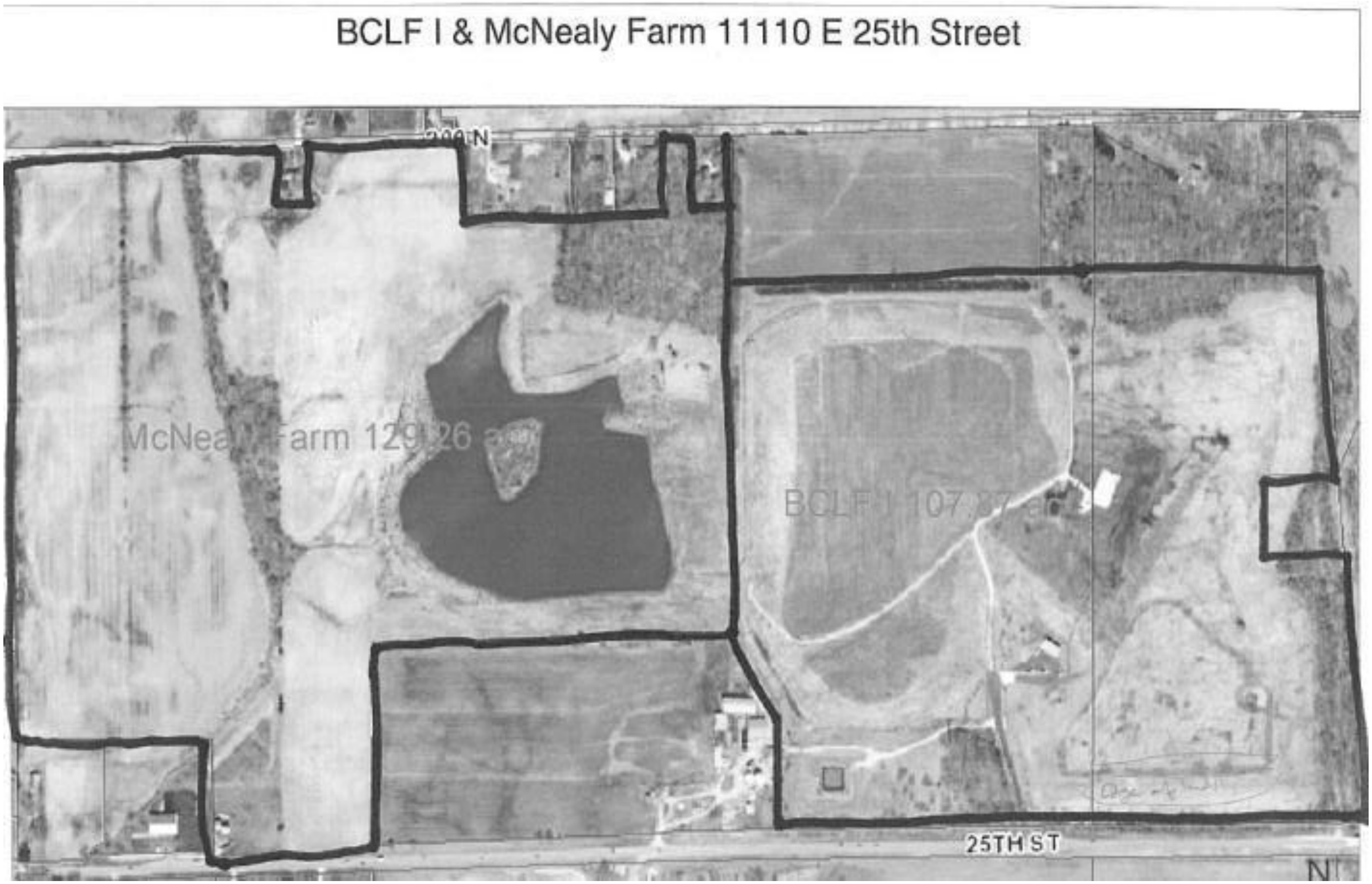


Figure 6 Petersville Site

Figure 7 Solar Flare in Petersville Site

After visiting the Petersville site, the Jonesville site was visited. The Jonesville site is the current landfill used by Bartholomew County and was not capped at the time of the site visit. At the time of the visit, the landfill was quoted to take in 72,000 tons of waste per year from approximately 50 garbage trucks per weekday and 250 small users per weekday. On weekends, the number of small users varies from 1200-1500 persons. Rumpke performs operations and contributes about 32,000 tons/year in commercial trash. Users of the landfill are not allowed to dump tires, Freon refrigerants, motor oil, lead batteries or acid from batteries or yard waste. Furthermore, there are two leachate collection ponds that collect between 1,000,000 – 2,000,000 gallons of leachate per year.

In terms of physical size, the landfill will eventually span an area of 250 acres after being fully capped. Physical features of the landfill include 5 acres of wetlands and 5 different types of soil. The wetlands bring fauna and flora that are used during educational tours. Figures 8-11 shown in the remainder of the section depict the physical traits of the landfill and a view of landfill operations.

Figure 8 Jonesville Site

Figure 9 Jonesville Site Operation

Figure 10 Jonesville Soil Layers

Figure 11 Jonesville Education Tours

Concept Development

Marketing Strategy

Once the landfill sites were investigated and the project was ready to move to the concept development phase, the team decided to reach out to the thoughts suppliers from the Customer Selection matrix performed previously. In order to obtain the experience of different users, various marketing channels were used. Figure 12 summarizes the different marketing channels used

Figure 12 Marketing Channels

The team worked together to develop an information booklet that summarized the intention of the project. The full booklet can be seen in the Appendix section of this report. Each of the other channels used targeted different audiences for information. The HHP Leadership Meeting and My Cummins article were used to target internal Cummins employees. The newspaper articles, radio announcements, and BCSWMD promotion were meant to target the general community. From these efforts, the team was able to obtain ideas from the following groups of people: Cummins employees through emails and brainstorming, various consulting engineers who were interviewed, and media suggestion from the newspaper article. The concept generation section covers the results of the interactions in greater detail. Figure 13 shows snapshots of the cover page for each of the media outlets used during the landfill projects. Bartholomew County was given copies of the full reports

Figure 13 Written Media Channels

Concept Generation

Interview Summaries

After obtaining a list of individuals who were interested in being interviewed, the 6S team made an interview guide that recommended asking the following questions:

1) What is the landfill size (sq. ft, acre) and age? What type of geographical features does the plant have?
2) What is the gas composition of the landfill? How has the landfill gas composition changed over time?
    a. How often does gas sampling occur?
3) Have any expansion plans of the landfill changed the quality of the gas?
4) Are there any current utilization methods of the landfill gas? If so, how is the gas collected and/or filtered?
5) Where there any tax credits/incentives that made utilization of the landfill easier?
6) Hardest thing to overcome in the process? (utilizing landfill, maintenance, etc)
7) What method(s) were/was not chosen and why?
8) Was there previous infrastructure at the landfill or did the infrastructure need to be developed?

These questions were posed to the plant managers of the benchmarked landfills who were selected using the EPA's LMOP database and by searching for nearby landfills of similar size to the two in this report. Unfortunately, only one landfill owner responded to the group's request to interview their landfill application. However, the interview proved very valuable because the landfill owner had historical knowledge of the Columbus, OH landfill from open to close. The author has summarized key pieces of information in the bullets below; however, the appendix contains the full un-edited notes from the conversation.

- The landfill is about 23 acres and was opened since the late 1800's.
- A nearby office building that was occupied in the 50's-80's had landfill gas piped for heating purposes
- While exact cost of piping is not available, one can conclude that the regulations around piping were not as stringent as today; however, the piping maintenance was the most difficult aspect of managing the landfill, mostly because of monetary reasons.
- Currently the landfill is a golf course that overlooks Columbus, OH. The full cost of this project was about $6,000,000.00 and was funded through a series of grants and county sponsorship. The break even life is a little over 30 years but the purpose of utilizing a vacant land lot and creating a beautification project was more important than break even period.

Besides interviewing landfill owners, persons with expertise in the field of landfill consulting or persons who would be potential partners for a landfill application. Non-Cummins professionals who were interviewed include:

- Ralph Slone from NOx Tech
- Tony DiPuccio from SCS engineering
- Gordon Parish from T&M associates
- Matthew D John from Ivy Tech
- Doug Day from Duke Energy Corporation.

The bullet points below highlight key pieces of information extracted from each of the interviews after reviewing the note transcript. The exact transcripts and notes can be found in the Appendix page of this report.

Interview with Gordon Parish

- Petersville landfill has a good potential for shop and green house that require 50-60 cfm
- When the county commissioner was approached with the possibility of doing a gas to energy project using a reciprocating engine, the project was not favored because of monetary risks and other unidentified risks.
- A general advise given to clients is to bring in develops that will pay for landfill costs and then share some percentage of the revenue.
- A good rule of thumb is to that each acre of landfill that is piped will cost about $25,000 for meet compliance and obtain gas
- About 2/3 of landfill gas projects are natural gas to electricity conversion while the remaining 1/3 are a direct use of the fuel. The fuel quality is generally considered a medium BTU fuel
- Hoosier Energy or Duke Energy may be willing to partner up with the landfill for a direct use application
- Co generation consultants have talked with GM and Honda in other areas, so perhaps Toyota & Cummins may want to partner up to be greener.
- Converting landfill gas to CNG or LNG fuels was not looked at as a possible project because of the high BTU value needed. Typically a landfill needs to generate at least 1500 cfm before the benefit outweighs the cost
- Gas piping project requires a lot less capital but is a good niche project if there is a nearby utility hookup

Interview with Ralph Slone

- NOx tech sells products that treat exhaust from IC engines
- For cleaning of gas, the cleaning station would need to clean gas containing CO_2, water, siloxanes, H_2S and then compress the gas

- Piping the gas directly into a boiler or running the gas through an IC engine would require a capital investment but minimal cleaning
- Typically gas composition is between 400 BTU/ft^3 and 500 BTU/ft^3 because of the CO2 content in the fuel
- The biggest issue with landfill gas being used in boilers is the siloxanes. Removing the siloxane is critical before piping gas to the boiler. Enkei Aluminum would be able to subsidize 40% of their needs through the landfill gas.

Matthew John

- A greenhouse is the biggest cost to having a partnership with Ivy Tech Ag program because one would cost about $25,000 to $30,000 but there is no available funding from Ivy Tech
    - The green house would be useful for teaching and research purposes including hydroponics and off season growing
- The plot next to the McNealy farm area would be useable as a research plot
- A potential source of self-funding after initial costs would be selling the vegetables from the research patch to the food pantry at Ivy Tech. Or the plants could be used for some type of community outreach
- Obtaining money for grants for the infrastructure is the major roadblock that Ivy Tech would have with this type of relationship. Another aspect that would be considered is that the services from the program would not compete with farmers.
- “There is no policy preventing partnership, however, Ivy Tech cannot accept a donation of funds for a greenhouse and then put it on property owned by someone else (the county). Either the donation would have to be to Bartholomew County for the greenhouse or the property would have to be long-term leased to ivy Tech like the airport land where the main campus is built. Our Foundation would not allow us to accept donations for permanent structures on property that Ivy Tech doesn’t own or control.”

Doug Day

- Duke Energy One group has been approached before about long term view of using the Jonesville Landfill.
- Main project type that Duke works with is selling electricity back to the grid. If the landfill is interested, they would be good people to contact to help tie the landfill with the section of Duke that is responsible for utility aspect.
- There are a number of grid regulations that would need to be reviewed prior to selling electricity to the grid. Julie S Orben sent an email regarding some of the policies on this topic. The author has summarized the grid policies in the bulleted sub section; the full transcript is available in the Appendix:
    - Indiana Utility Regulatory Commission does not allow infrastructure to be donated since the cost of the donation would be at the expense of rate payers.
    - Upgrades would need to occur in order to handle the power sent back to the grid from a power generation application

  - A recommendation of reviewing the Riders and agreements first before going any further on a potential partnership was given

Tony DiPuccio

- There is no obligation from the EPA to put solar flares in. BCSWMD does this to be a good neighbor. All that is required by the permit is a passive system (trenches cut every 100 ft down into the waste). So no vertical walls
- One possible scenario is putting off capping until the end of the landfill (probably not useful but an idea)
- Operation considerations include:
  - The $25,000 estimate is only material and labor cost (installation)
  - The installation of gas collection system will probably not be done until 15-20 years from now
  - If direct piping is used, how many owners will you need to get through if BCSWMD owns the pipe outside of its own land plot? And what safety considerations are there?
  - One possible mitigation technique would be to use a third party utility company or that BCSWMD accepts the risk of becoming a utility after crossing their property line
  - Becoming your own well field operator. A 3^{rd} party operator will typically try to pull as much gas from the landfill as possible while the owner is trying to consider landfill safety and regulations. This usually results in a lose-win or lose – lose scenario.
  - The first piping installation is what would handle the highest cfm load (so the biggest pipe and biggest cost)
  - One should consider a 2 inch to 4 inch sump for condensate (leachate) that is then pumped to the leachate collection system. Sometimes can be passive flow forced by gravity but generally the leachate is actively pumped out of the well. This prevents the well from being filled with liquid instead of gas
  - Construction and demolition debris (dry wall – gypsum) usually a sulfides contributor
- Application considerations include:
  - For direct use, there is not much gas cleaning required because the gas is usually thrown into a boiler.
  - Things to consider for a grid application are whether one will tie in using direct burial or conduits. Either way, the equipment for phase changing will cost roughly 0.25 to 0.5 million dollars
  - Working with a utility can be challenging because project timelines sometimes do not match.
  - Fuel cost is the hardest lever to control because one has no control over it!

After assessing the considerations needed for landfill utilization projects, the group decided to move forward with drawing schematics for possible ideas. At this point, the information booklet referenced in the marketing channel section was pivotal in communicating the intent of the 6S team.

Brainstorming Activity

On February 6, 2013, the team held a brainstorming activity that was open to all Cummins employees. This activity used the KJ as a model for gathering ideas and inputs from the internal Cummins community. High-level concepts as well as details that were considered important to the success of these concepts were considered, but no concepts were eliminated from consideration. Figures 14 and 15 show the setup and format of the brainstorming session. Figures 16 and 17 depict some of the ideas contributed by the participants.

Figure 14 Brainstorming Activity (Format of Forum)

Figure 15 Brainstorming Participation

After the brainstorming activity, the input was formatted into power point. Figures XX and XX depict the type of ideas that were given by the participants of the brainstorming activity, which totaled 20 individuals. The Appendix contains the full brainstorming recap power point slides.

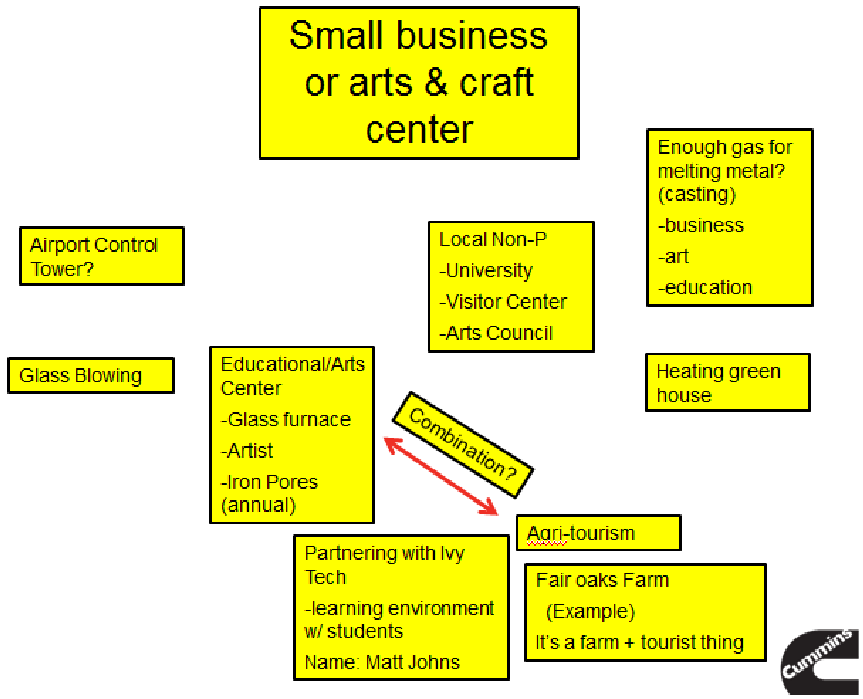


Figure 16 Petersville Site Brainstorming Outcome

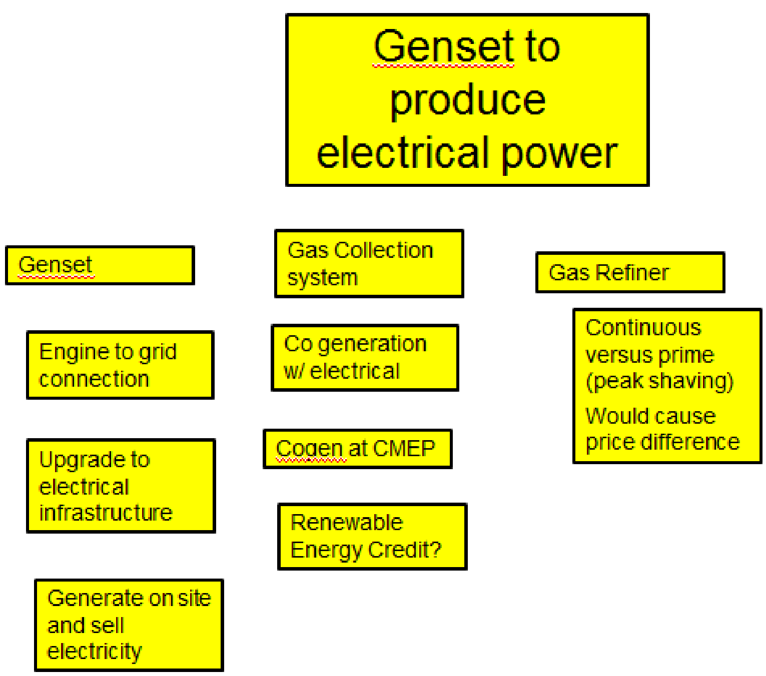


Figure 17 Jonesville Site Brainstorming Outcome

Final Concepts

After obtaining feedback from employees, field experts, and the general population, the group began drawing simple schematics for different ideas. These sketches began by hand and went through a number of iterations before finally developing into the power point slide images shown below. Note that each slide shows different characteristics of each idea.

Petersville site

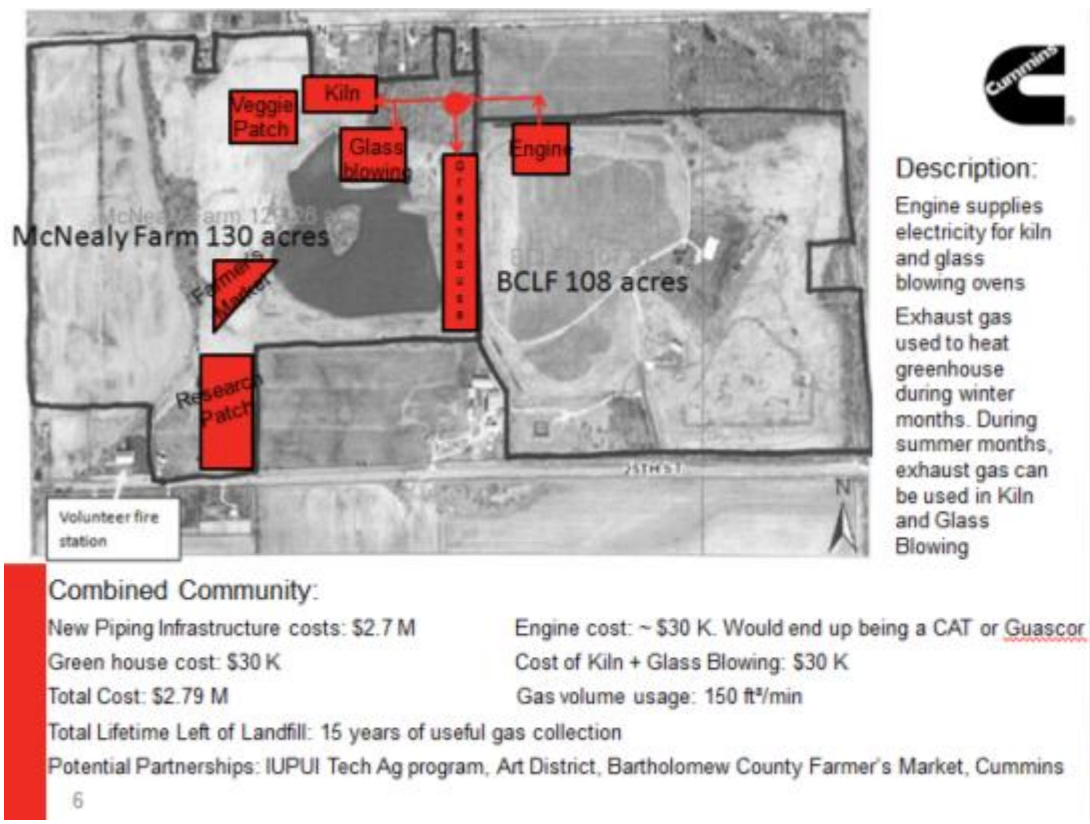


Figure 18 Combined Community Project with New Piping

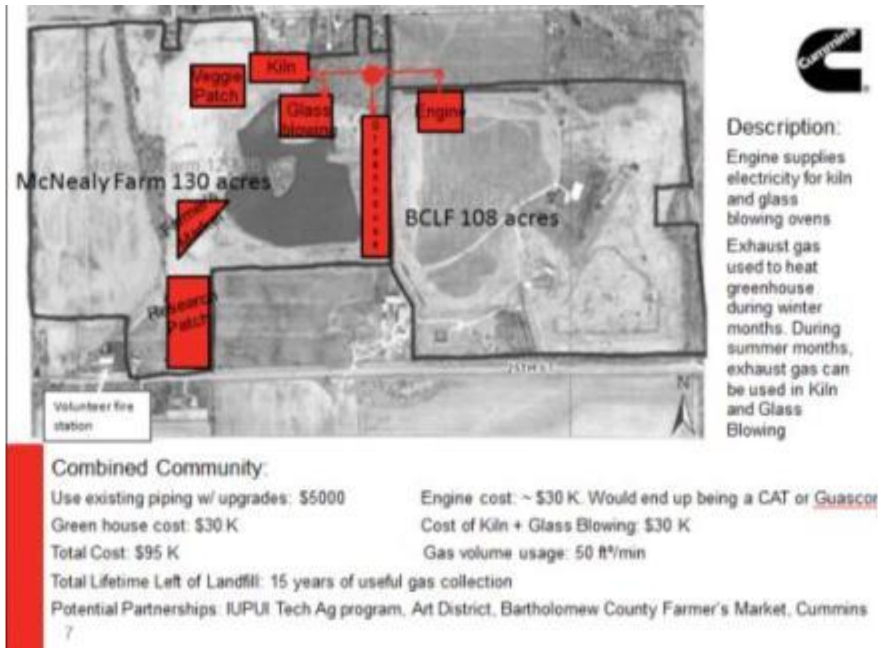


Figure 19 Combined Community with Existing Piping

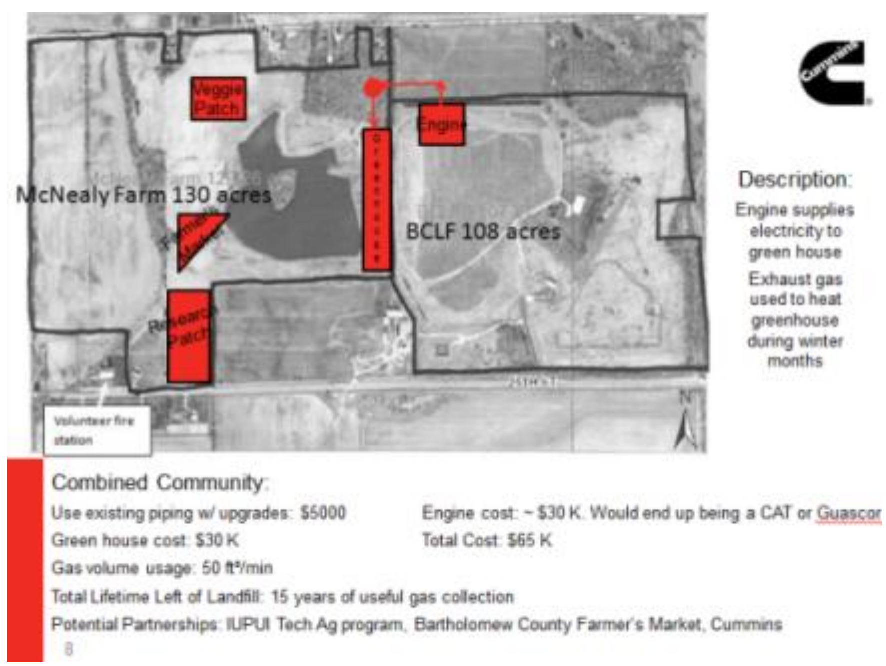


Figure 20 Agricultural Focused Project

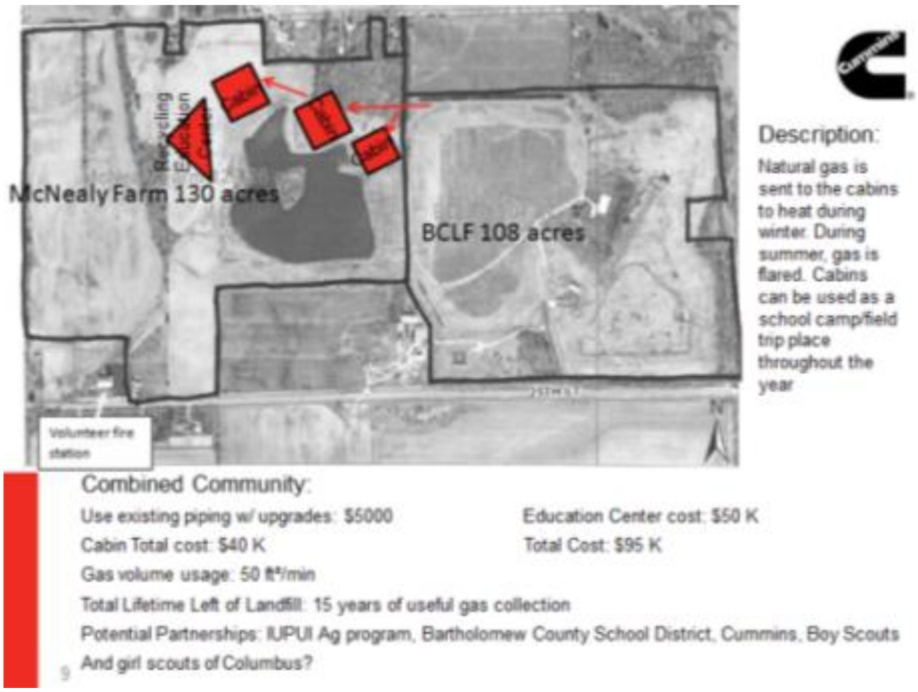


Figure 21 Cabin Oriented

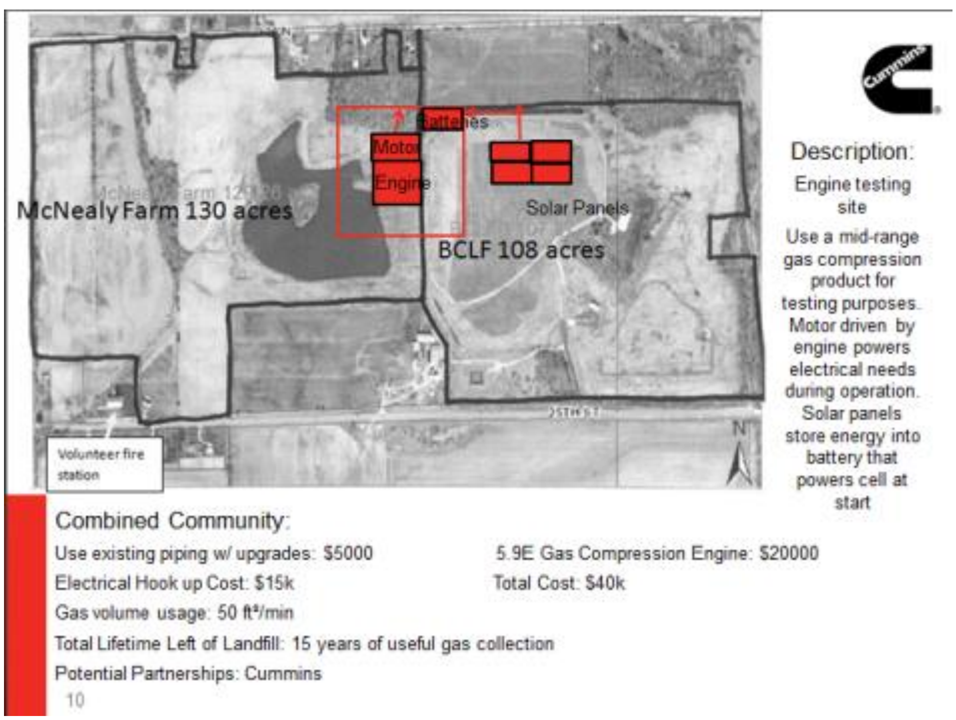


Figure 22 Test Cell Oriented

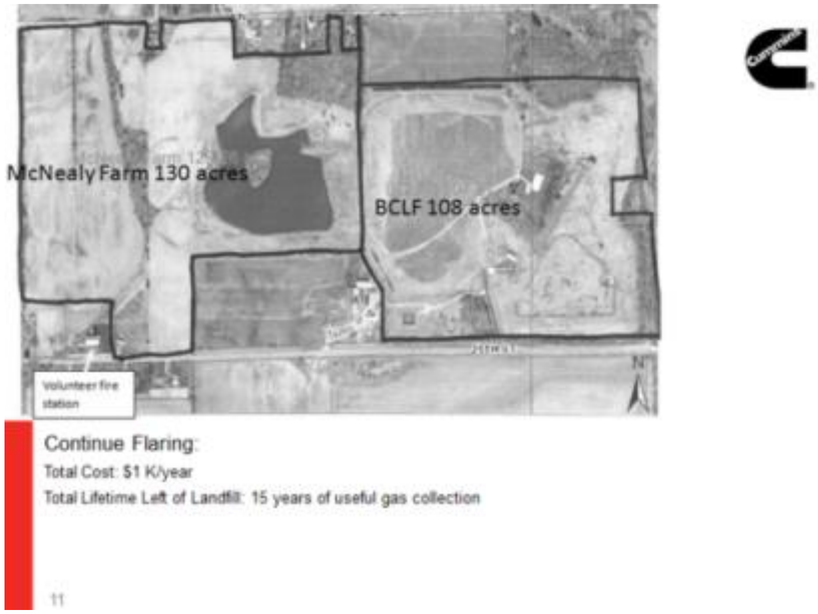


Figure 23 Continuous Flaring

Jonesville Site

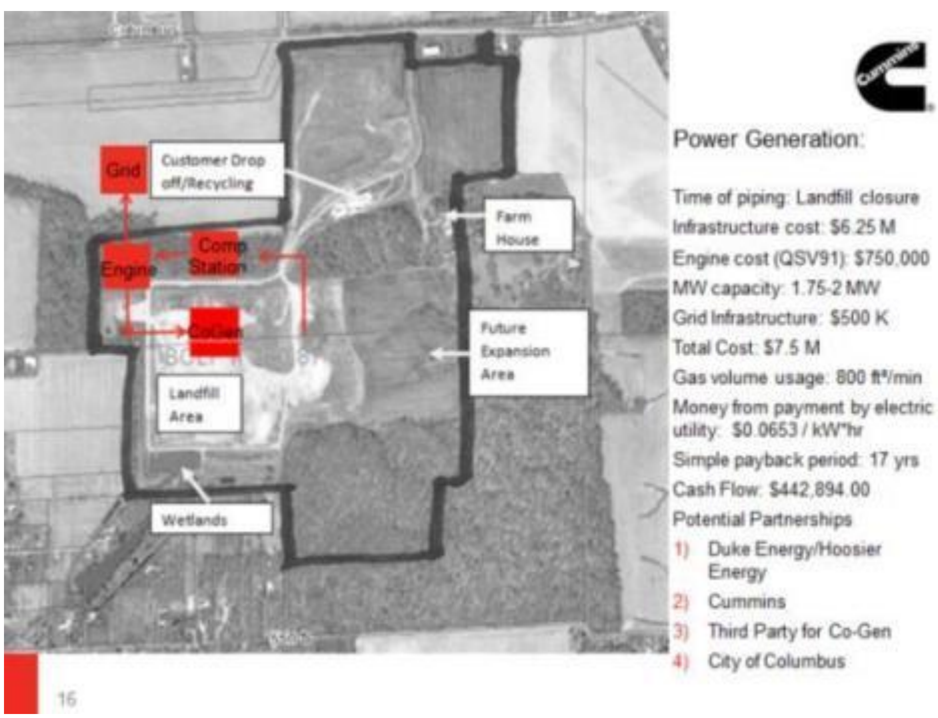


Figure 24 Power Generation Scenario 1

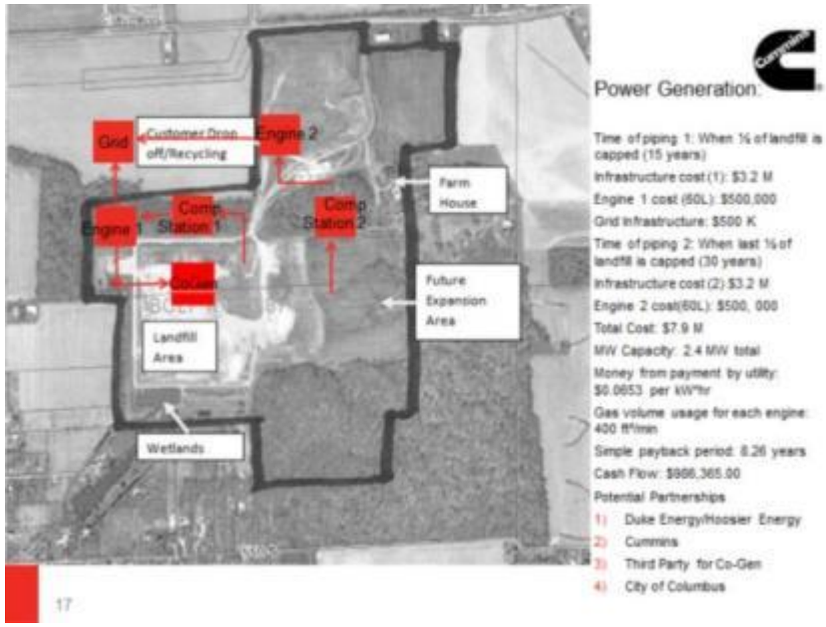


Figure 25 Power Generation Scenario 2

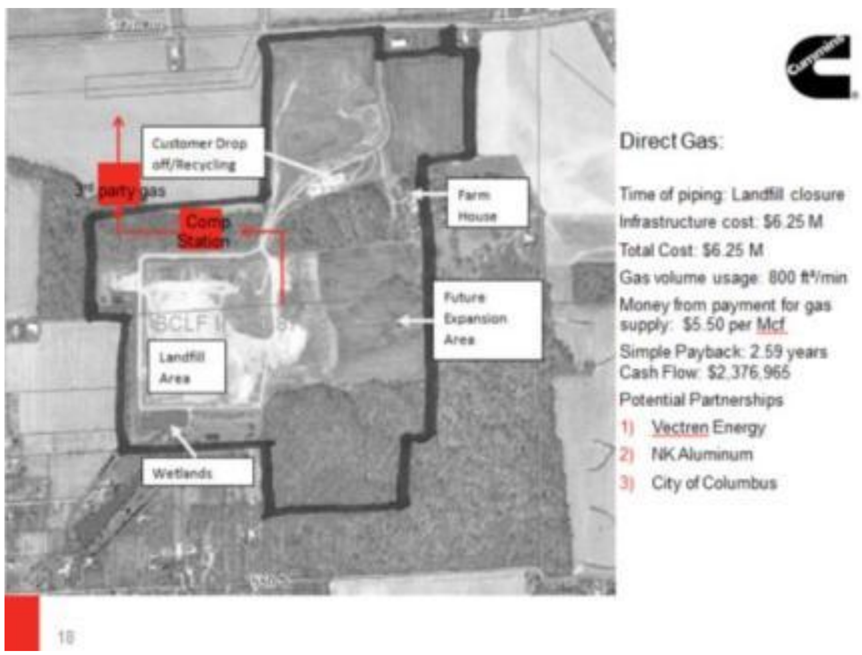


Figure 26 Direct Use to Gas Utility

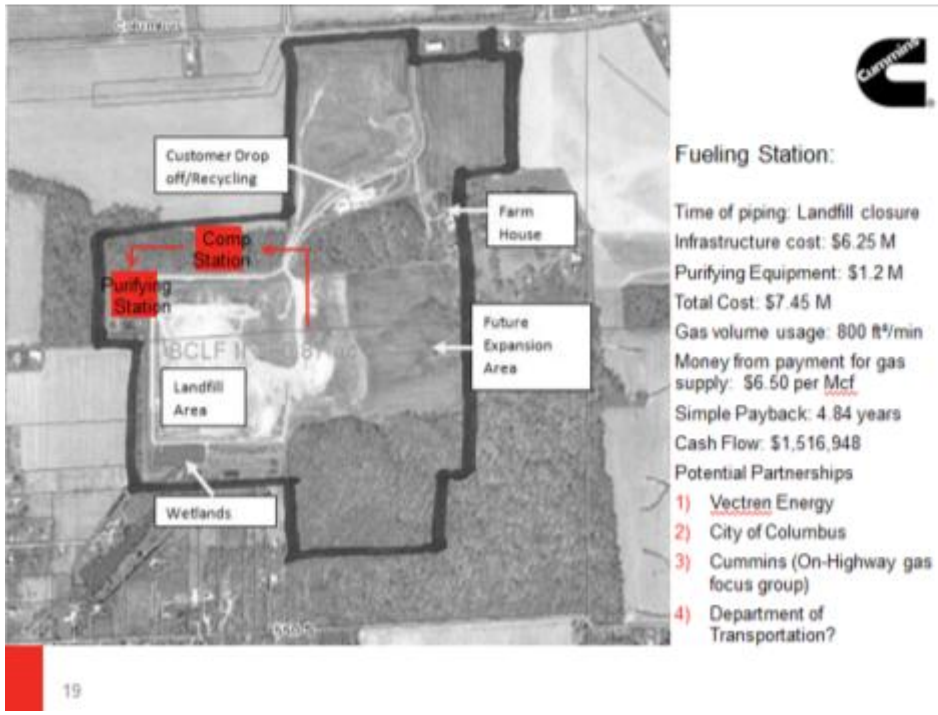


Figure 27 Gas Fuel Station

Measuring and Ranking Concepts

Metric Generation

In order to formulate metrics to begin the feasibility section of the project, the initial VOC was used in to fill in a QFD. Because the Petersville and Jonesville sites had distinct characteristics, the team decided to have a QFD done for each site. From the QFD, the 6S team obtained the functional product requirements that were the most important in ranking. The functional requirements were then transcribed to the C&E ranking matrix, which is described in the Ranking section. Tables 5 and 6 describe the functional product requirements of the QFD for the different sites and Figures 28 and 29 show a screenshot of the QFD process.

Table 5 Petersville Metrics

Functional Product Requirement	Relative Importance
Time to project Start	200
Initial Capital Investment	320
# of community partners engaged in project	358
Initial Gas placement needed to start project	150
Total % of Available Gas Used	122
Likelihood of being funded over various project stages	348
Time for project to start using gas	188
Application Greenhouse Gas Offset	304

		Functional Product Requirements (Measurable Design Parameters)							
Maximize, Minimize, or Target		-	-	+	-	-	+	-	
Customer Needs	**Importance Rating**	Time to project Start	Initial Capital Investment	# of community partners engaged in project	Initial Gas placement needed to start project	Total % of Available Gas Used	Likelihood of being funded over various proj	Time for project to start using gas	Application Greenhouse Gas Offset
Dollar amount for initial investment of project	9	3	9	9	1	1	9	3	9
Wet Landfill Ideas will not be used	9	1	1	3	1	1	1	1	1
Project should be feasible to set up and start in 4 years	8	9	3	3	9	1	3	3	9
The less sand a project will require, the better rating	3	1	3	1	1	1	1	1	1
Concept will not reside on wetland area	1	1	1	1	1	1	1	1	1
Must meet title 2 air permit & leechate collection policies	7	1	3	1	1	3	1	3	9
The concepts should incorporate community partners	5	3	9	9	3	1	9	1	1
Enhanced relationship between BCSMWD and Cummins CIT teams	8	1	3	3	1	1	3	1	1
Environmental Stewardship - community benefits	4	1	1	3	1	9	1	1	3
ROI or Payback Period	8	3	9	1	1	1	9	9	3
Public Branding Potential	6	1	1	9	1	1	9	1	3
Usage of the McNealy Farms	8	3	3	9	1	1	3	1	1
Relative Importance (Priorities)		200	320	358	150	122	348	188	304
Target Range (with Units)		Within 1.5 years of proj	= 0 after funding	>2	< 40,000 million BTU/y	~90-100%	>90%	Within 3 years	> 0 GHG

Figure 28 Petersville QFD

Table 6 Jonesville Metrics

Functional Product Requirement	Relative Importance
Time to project Start	207
Initial Capital Investment	297
# of community partners engaged in project	225
Initial Gas placement needed to start project	141
Total % of Available Gas Used	181
Likelihood of being funded over various project stages	313
Time for project to start using gas	173
Application Greenhouse Gas Offset	229

		Functional Product Requirements (Measurable Design Parameters)							
Maximize, Minimize, or Target		-	-	+	-	-	+	-	+
Customer Needs	Importance Rating	Time to project Start	Initial Capital Investment	# of community partners engaged in project	Initial Gas placement needed to start project	Total % of Available Gas Used	Likelihood of being funded over various project stag	Time for project to start using gas	Application Greenhouse Gas Offset
Dollar amount for initial investment of project	9	3	9	3	1	1	9	3	9
Wet Landfill Ideas will not be used	9	1	1	1	1	1	1	1	1
Project should be feasible to set up and start in 4 years	2	9	3	3	9	1	3	9	9
The less sand a project will require, the better rating	2	1	3	1	1	1	1	1	1
Concept will not reside on wetland area	7	1	3	1	1	1	1	1	1
Must meet title 2 air permit & leechate collection policies	7	3	3	3	1	3	1	3	9
The concepts should incorporate community partners	5	3	9	9	1	3	9	1	1
Enhanced relationship between BCSMWD and Cummins CIT teams	8	3	3	9	1	1	9	1	1
Environmental Stewardship - community benefits	4	3	3	3	1	9	3	1	3
ROI or Payback Period	8	9	9	3	9	9	9	9	3
Public Branding Potential	6	3	1	9	1	3	3	3	3
Relative Importance (Priorities)		207	297	225	141	181	313	173	229
Target Range (with Units)		n after this CISS project has been completed	= 0 after funding	>2	400-600 ft^3/min	70-90%	>90%	Within 20 years	> 0 GHG

Figure 29 Jonesville QFD

Financial Calculations

After completing the metric generation, the group decided that a financial study would need to be conducted to properly compare the cost aspects of the different projects. For both sites, estimated costs were researched for items such as engine cost, estimated building cost, piping cost, etc. In addition, when considering investments in active piping systems, the fixed rate was $25,000 per acre of landfill piped. This data is shown on the individual power point slides in the final concept section.

In order to determine gas quality and quantity, the team referenced the notes from the interviews and the EPA landfill literature “Project Development Handbook” Chapters 3 and 4. The gas quality for both landfills was assumed to have an average of 45% Methane content, which translates to approximately 450 BTUs/ft^3. The gas quantity for each landfill was based on Figures 4 and 5

For the Jonesville site, a few assumptions were made in the financial calculation, which were needed in order to make data driven estimates on fuel price, loan terms, life of the project, and kWh rate. In addition to the estimates, the financial equations used to generate the model will also be explained.

For the direct use applications, the average fuel price needed to be determined for revenue purposes. The fuel price was based on a graph found on Geology.com that is shown in Figure 30. Since natural gas prices fluctuated in the last 10 years, an average was taken at each data point between 2000 and 2010. The average price of gas at the wellhead was $5.50 per Mcf, where M indicates thousand. This dollar quantity is assumed as the average price a utility would be willing to pay as well. However, the price would go up by $1.00 per Mcf if the gas were purified of the aggressive gas constituents. This price increase was verified by Ismael Chang from Cummins Inc.

For power gen applications, the average kWh rate needed to be determined for revenue purposes. The average rate was viewed in a table created by the EPA for average kWh rate in February of 2013 that was paid by the end user. For the state of Indiana and for an Industrial customer, the rate was 6.53 cents/kWh.

The loan term and project life were determined by inquiring BCSWMD on the city’s typical practice for long term loans. From Jim Murray’s perspective as landfill operator, loan terms are typically between 20-30 years. The landfill would most likely generate enough gas for a medium sized project for approximately 30 years, so an assumption was made that the landfill would generate gas only through the duration of the loan life. Typical municipal loan interest rates and payment methods were also given by Jim. For BCSWMD, the annual loan interest rates were 5-9% and the loan payment method used was the equal payment method.

In addition to researching typical values and ranges of items, the team used equations 1-6 to model the different concepts.

Equation 1

Equation 2

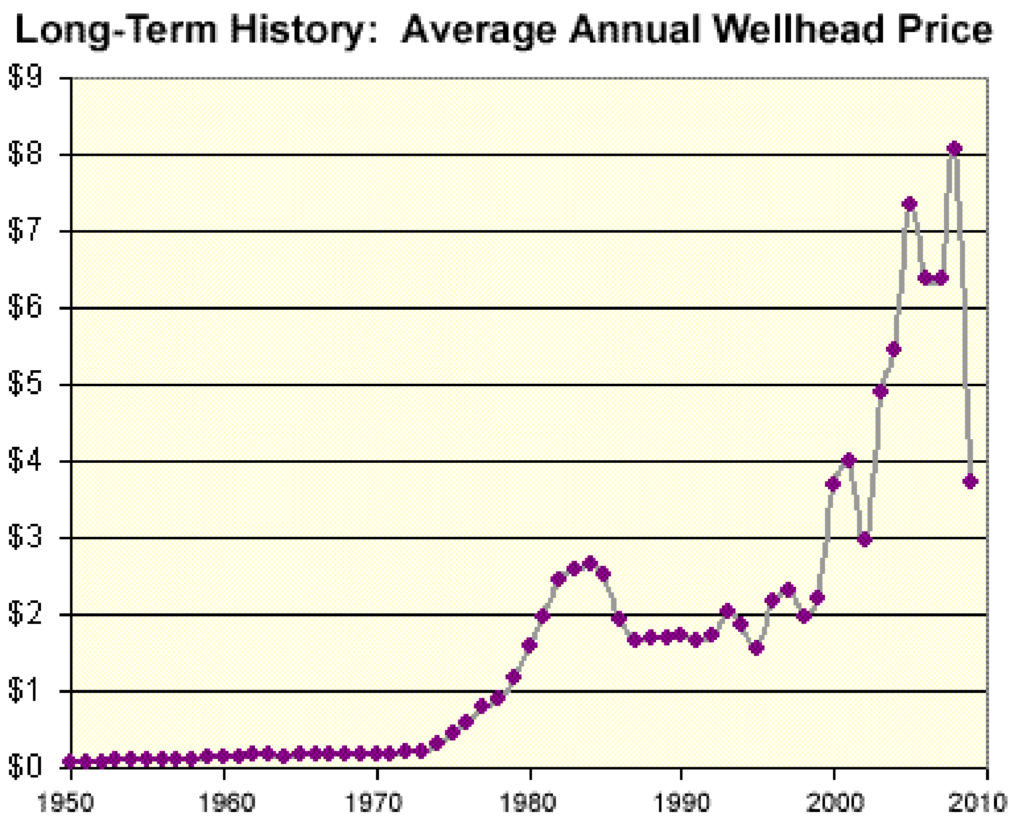
Equation 3

Equation 4

Equation 5

Equation 6

Note: The constants in Annual Revenue are conversion factors



A graph showing the long-term history of average annual wellhead prices for natural gas produced in the United States. In the 1950's and 1960's the number of homes and businesses supplied with natural gas was growing and a diversity of uses were being promoted. The rapid rise in price starting at about year 2000 was related to an overall increase in natural gas demand and rising energy prices in general. The sharp decline in average annual price that occurred in 2009 was in response to a global economic collapse that drastically cut demand. At the same time an abundance of new natural gas fields were being discovered and that excess supply placed additional downward pressure on prices.

The graph was prepared by the U.S. Energy Information Administration and is based upon monthly average prices for the United States.

Figure 30 Landfill Prices Overtime

Note: Figured found on geology.com

Simulation Study

The simulation study conducted used a combination of Excel and Mini Tab in order to generate the Annual Revenue, Simple Payback Period, and NPV of each project. Figure XX shows the parameters looked at and their low and high value range for the power generation applications, and figure XX depicts this for the direct use applications. After completing the assumptions portions, Mini Tab was used to generate a factorial design, which varied the parameters between high and low. A total of 128 variations were done for each of the parameters which were then used to calculate the annual revenue, NPV, and simple payback. Figures 31 and 34 show screen shots of the tools in use for the different application types.

Factor	Low	High	Unit	Notes
Initial contribution	-	2,000,000.00	$	Low based on sale of engine. High is based on approximately
Down Payment	0.1	0.3	%	Rest is assumed financed on loan with municipality
Loan Interest Rates	0.05	0.09	%	(general average is 6-8% so 7%+-2)
Term of the Loan	20	35	years	Average Loan Term
Inflation Rate	0.01	0.03	%	Average from last 30 years
kWh rate	2.5	7	cents per kWh	
Usage	0.6	1	%	60% engine utilization rate versus 100%
kW generated	1200	2000	kW	Engine sizing

Figure 31 Power Generation Factors

Factor	Low	High	Unit	Notes
Initial contribution	-	2,000,000.00	$	Low based on sale of engine. High is based on approximately 1/3 of project cost
Down Payment	0.1	0.3	%	Rest is assumed financed on loan with municipality
Loan Interest Rates	0.05	0.09	%	(general average is 6-8% so 7%+-2)
Term of the Loan	20	35	years	Average Loan Term
Inflation Rate	0.01	0.03	%	Average from last 30 years
Fuel Price	3	8	$	Low end has been $3 and high has been $8 in the last decade
BTU value	400	500	BTU/ft^3	fuel BTU value
Gas Flow Rate	600	1000	ft^3/min	gas flow rate

Figure 32 Direct Use Factors

Initial Contribution	Down Payment	Loan Interest Rate	Term of the Loan	Inflation Rate	kWh Rate	Usage	kW generated	Loan Yearly Payment	Yearly cash flow	NPV	Simply Payback
-1	-1	-1	-1	1	1	-1	-1	($534,149.51)	($413,693.51)	($13,172,441.58)	-16.09
-1	1	-1	1	-1	1	1	-1	($316,193.91)	$94,566.09	($4,707,045.46)	54.75
1	1	-1	1	-1	1	-1	-1	($230,693.52)	($110,237.52)	($8,531,248.45)	-34.27
1	-1	1	1	1	-1	1	1	($459,616.31)	($342,616.31)	($12,444,644.60)	-14.18
1	-1	1	1	-1	1	1	1	($459,616.31)	$434,983.69	$6,973,746.79	11.17
-1	1	-1	-1	1	1	1	-1	($415,449.62)	($4,689.62)	($7,461,792.98)	-1104.02
-1	-1	1	1	-1	-1	-1	-1	($629,960.82)	($789,440.82)	($29,846,425.04)	-8.43
1	1	1	1	1	-1	1	-1	($357,479.35)	($413,279.35)	($13,898,330.25)	-9.14
1	-1	1	-1	1	-1	1	-1	($532,032.56)	($587,832.56)	($13,603,829.04)	-8.26
-1	1	1	1	-1	-1	1	-1	($489,969.52)	($545,769.52)	($22,916,903.26)	-9.49
1	1	1	1	-1	-1	-1	-1	($357,479.35)	($516,959.35)	($20,097,599.87)	-7.31
-1	-1	1	1	-1	-1	1	1	($629,960.82)	($512,960.82)	($21,983,889.58)	-12.98
-1	-1	-1	-1	1	-1	1	-1	($534,149.51)	($589,949.51)	($15,633,386.58)	-11.28
1	1	-1	-1	-1	-1	-1	-1	($303,109.99)	($462,589.99)	($13,295,021.94)	-8.17
-1	1	1	-1	1	-1	1	-1	($567,168.17)	($622,968.17)	($16,094,404.10)	-8.31

Figure 33 Power Generation Simulation

Initial Contribution	Down Payment	Loan Interest Rates	Term of the Loan	Inflation Rate	Fuel Price	BTU Value	Gas Flow Rate	Loan Payment	An	NPV	Simple Payback
1	1	-1	-1	1	1	-1	-1	($232,897.73)	$690,430.27	$7,369,438.48	4.20379
1	-1	1	1	1	-1	1	1	($353,150.99)	$352,449.01	$1,511,867.74	10.5879
-1	1	-1	-1	1	-1	1	1	($345,237.35)	$360,362.65	$1,058,865.73	11.9391
-1	-1	-1	-1	-1	-1	1	1	($443,876.60)	$261,723.40	($808,739.94)	21.1356
-1	-1	-1	1	1	1	1	-1	($337,829.36)	$834,330.64	$6,881,049.69	6.63009
-1	1	-1	-1	1	-1	-1	-1	($345,237.35)	($43,989.35)	($4,956,870.98)	-97.806
1	-1	1	1	1	1	-1	1	($353,150.99)	$1,233,729.01	$14,623,088.78	3.02472
-1	-1	-1	-1	1	-1	1	-1	($443,876.60)	($49,316.60)	($6,265,389.91)	-112.167
1	-1	1	-1	1	1	1	1	($408,792.77)	$1,592,807.23	$19,965,265.97	2.34283
1	1	1	-1	1	-1	-1	-1	($317,949.93)	($16,701.93)	($3,150,903.11)	-173.778
1	1	-1	1	-1	1	-1	-1	($177,255.78)	$746,072.22	$10,560,865.35	3.89027
1	-1	-1	-1	-1	1	-1	-1	($299,439.94)	$623,888.06	$7,526,721.56	5.98134
1	1	1	1	-1	1	1	-1	($274,672.99)	$897,487.01	$13,293,228.79	3.23394
1	-1	-1	-1	1	-1	1	1	($299,439.94)	$406,160.06	$2,310,952.60	9.18772
-1	1	-1	-1	1	1	-1	1	($345,237.35)	$1,241,642.65	$14,170,086.78	3.4651

Figure 34 Direct Use Simulation

After completing the simulations, the data was inserted into a Minitab and main effect plots were generated. The plots generated depict the influence from factors that are used to calculate annual cash flow, NPV, and simple payback. A greater slope means that the factor has a bigger influence on the final output value than other factors. Table 7 summarizes the factors with the strongest influence on the annual cash flow, simple payback, or NPV calculations. Figures 35 – 43 show the individual main effect plots for the different concepts.

Table 7 Summary of Main Effect Plot Strongest Influencing Factors

Project Type	Yearly Cash Flow	Simple Payback	NPV
Power Generation	kW rate, Usage, kW generated	Down payment, Initial Contribution, Loan term	kWh rate, Usage, kW generated, Initial contribution
Direct Flow to Utility	Fuel Price and Gas Flow Rate	Down Payment, Initial Contribution, Loan Term	Fuel Price
Fuel Station	Fuel Price and Gas Flow Rate	Down Payment, BTU Value, and Loan Term	Fuel Price

Power Generation

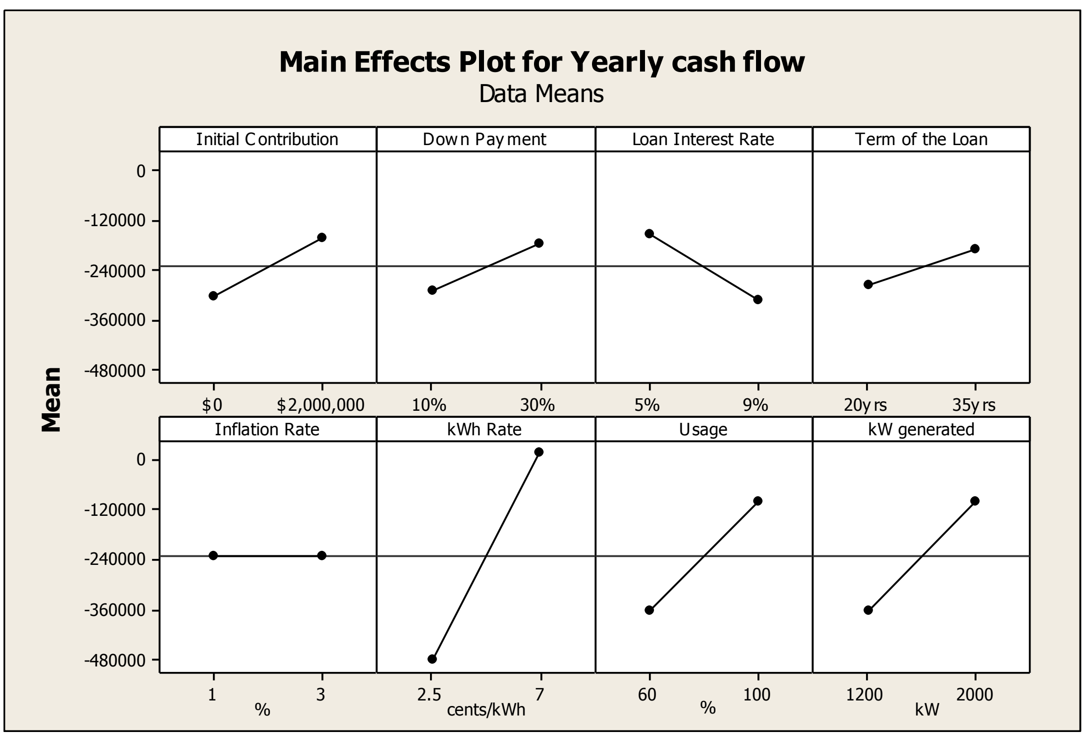


Figure 35 Main Effects Plot for Yearly Cash Flow – kWh rate, usage and kW generated influence yearly cash flow the most

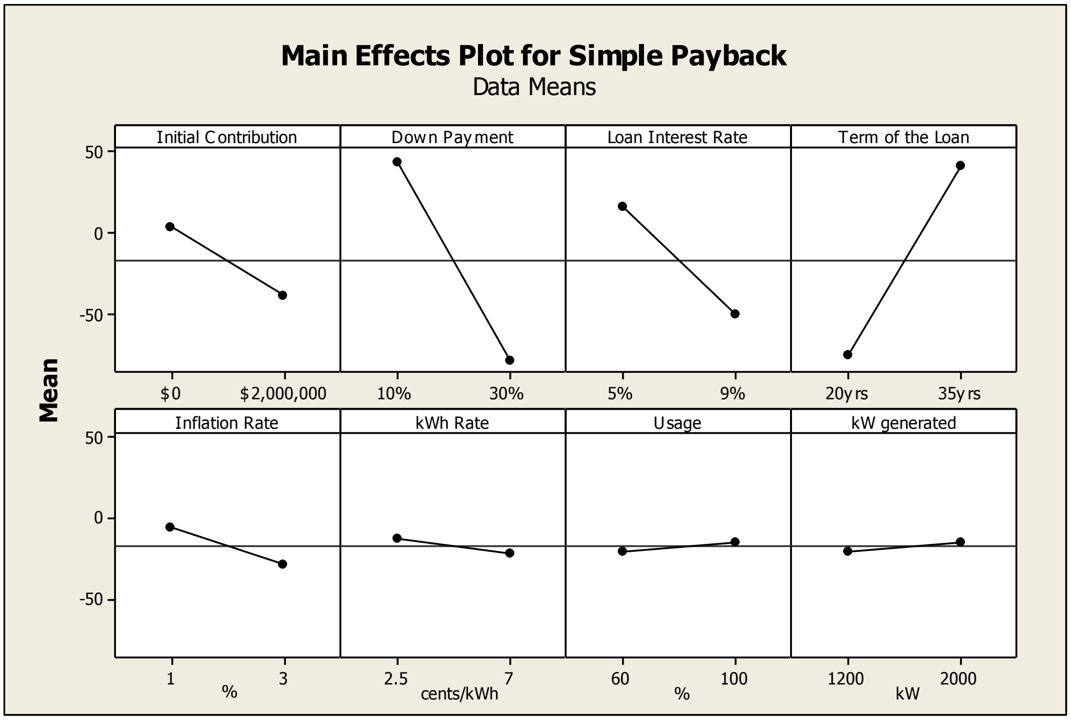


Figure 36 Main Effects Plot for Simple Payback – down payment, initial contribution, and loan term influence simple payback the most

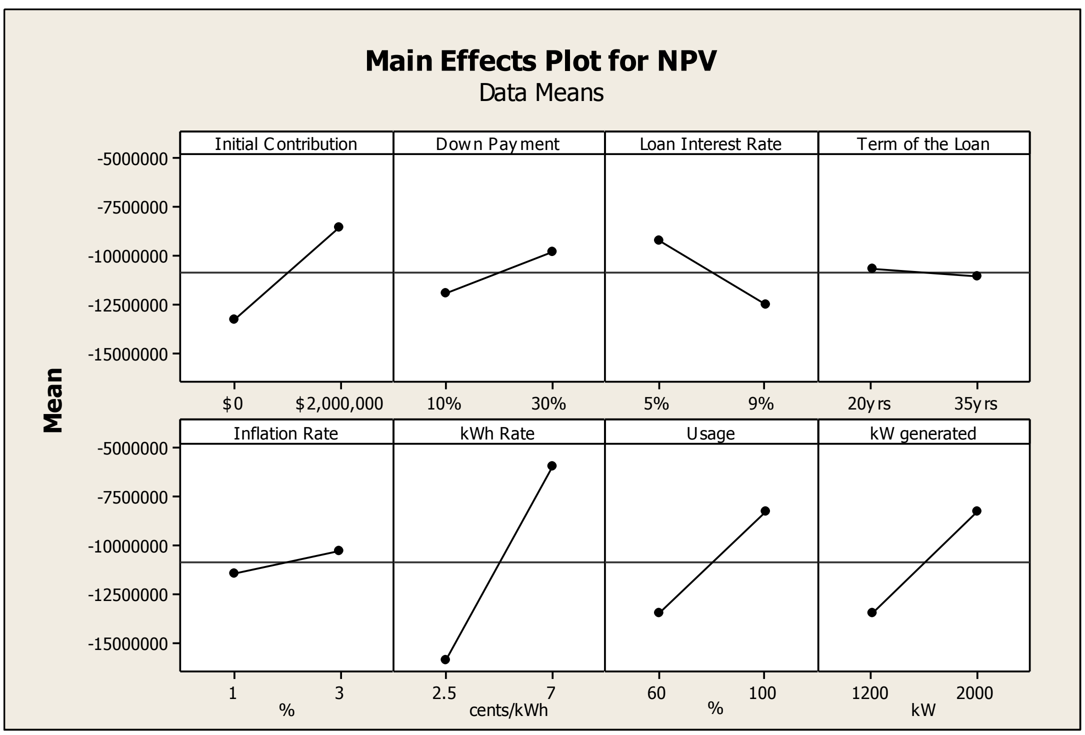


Figure 37 Main Effects Plot for Net Present Value – kWh rate, usage, kW generated, and initial contribution influence NPV the most

Direct Flow to Utility

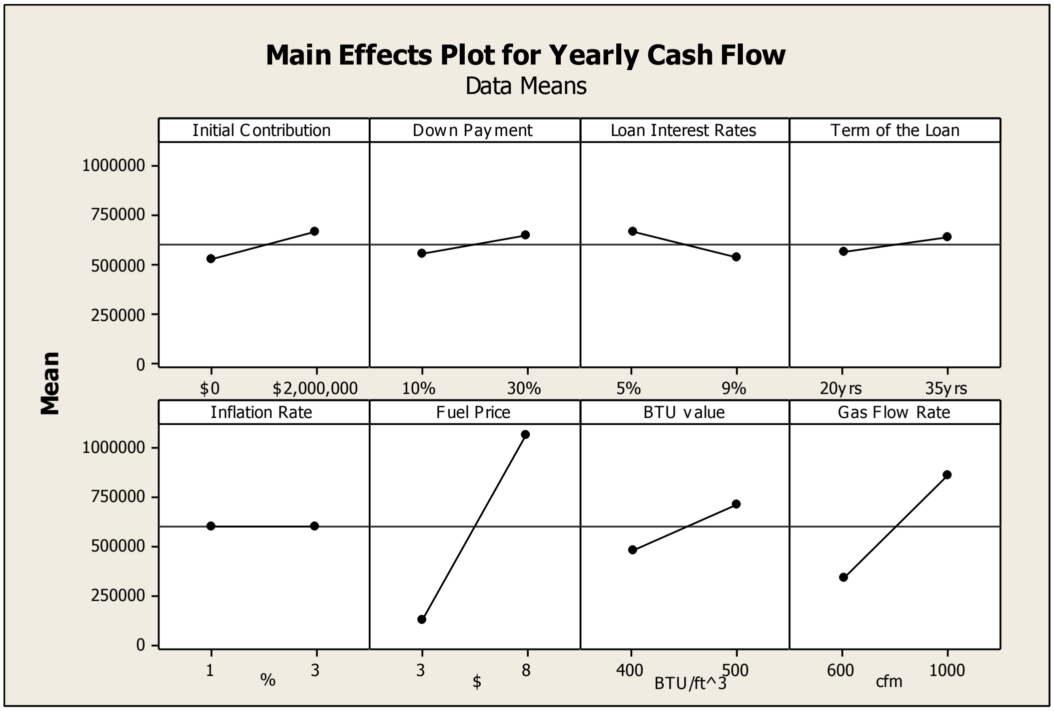


Figure 38 Main Effects Plot for Yearly Cash Flow – fuel price and gas flow rate influence yearly cash flow the most

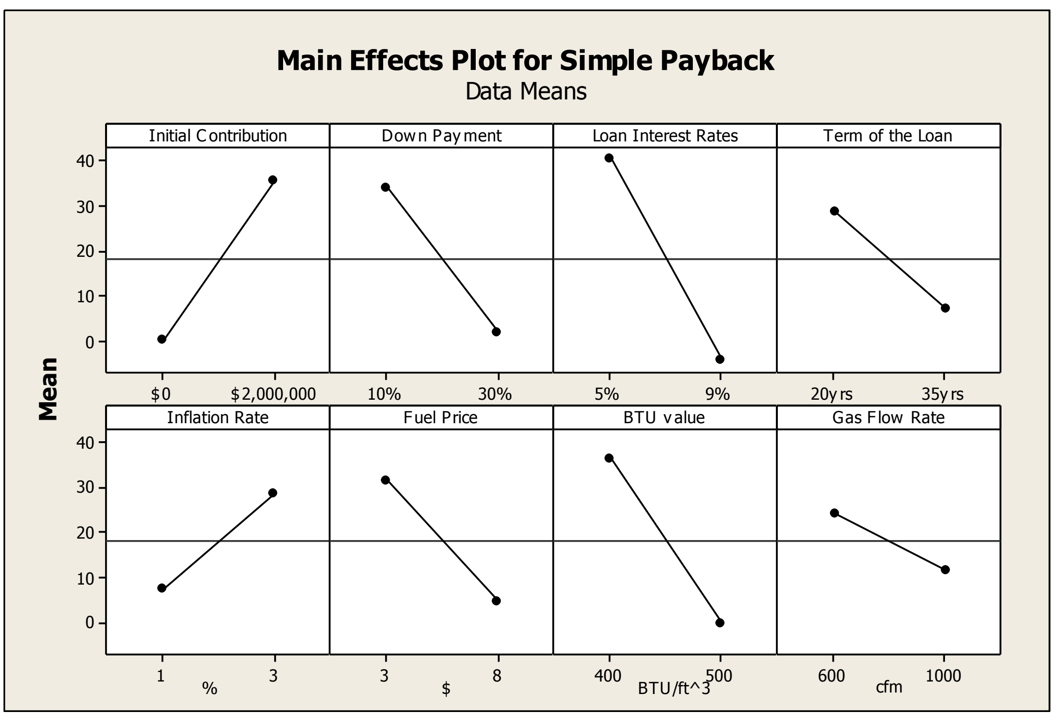


Figure 39 Main Effects Plot for Simple Payback – down payment, initial contribution, and loan term influence simple payback the most

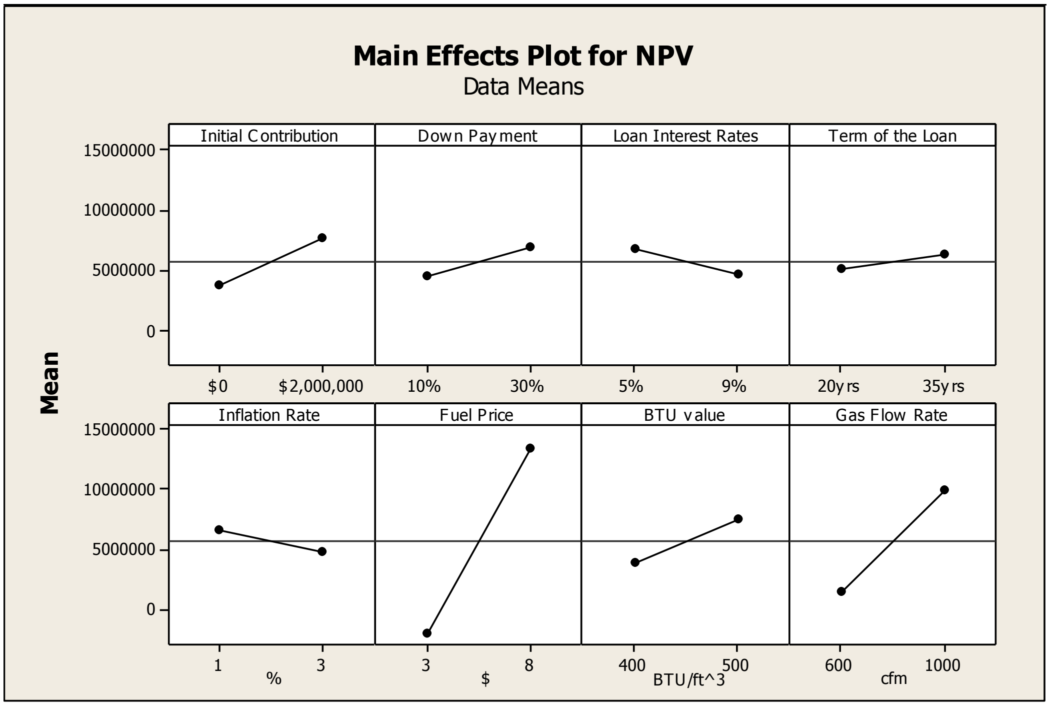


Figure 40 Main Effects Plot for NPV – Fuel price influences NPV the most. The other factors appear to have a statistically equal significance on the NPV value.

Fuel Station

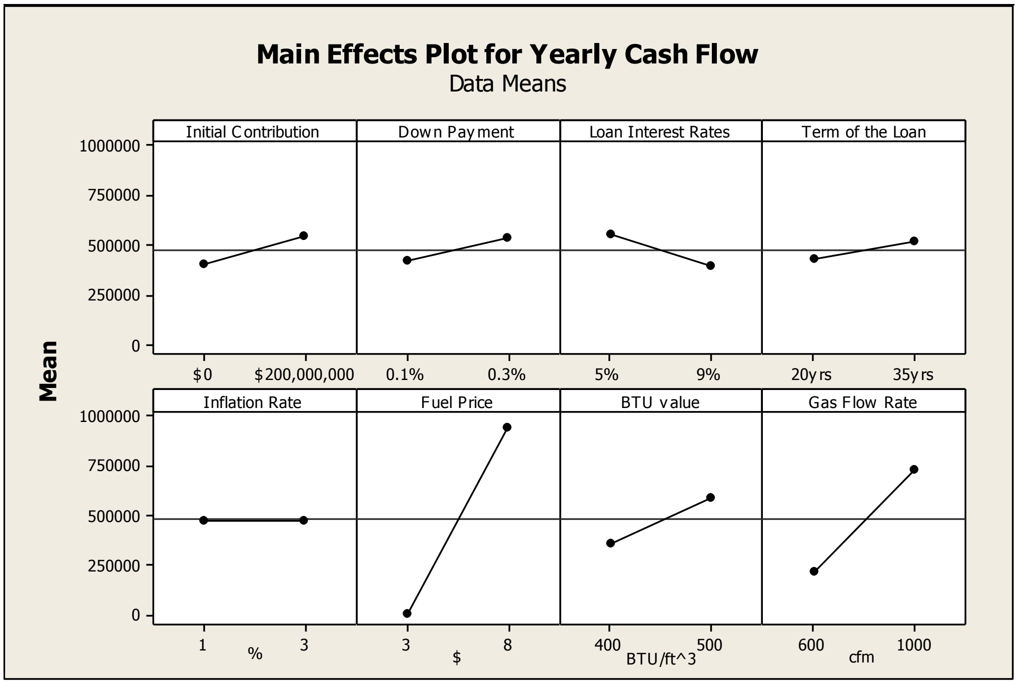


Figure 41 Main Effects Plot for Yearly Cash Flow – fuel price and gas flow rate have the strongest influence on yearly cash flow

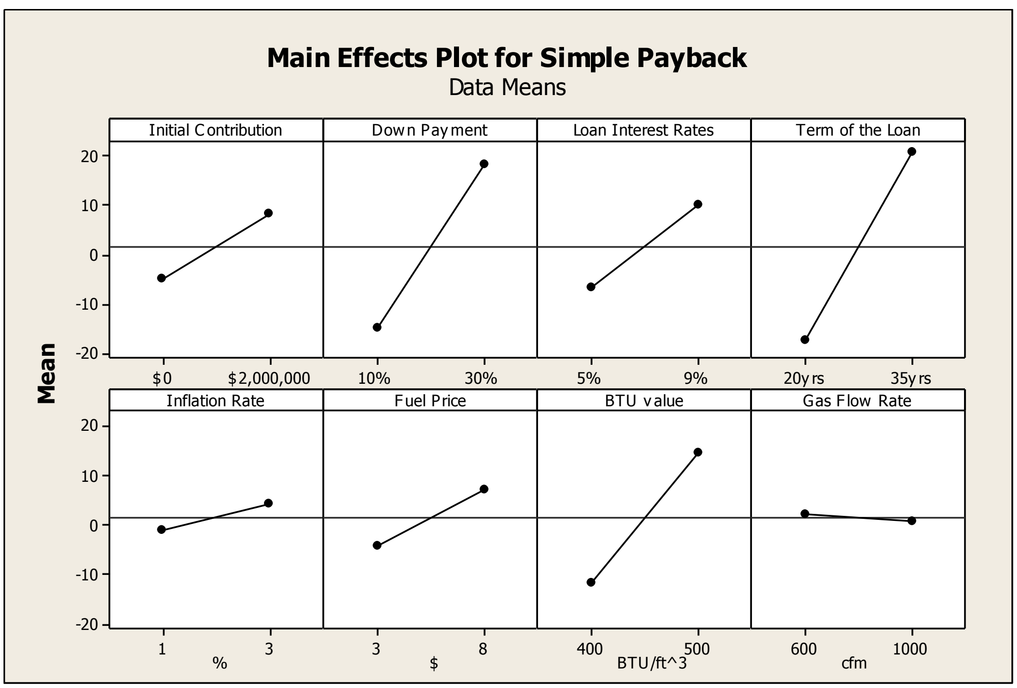


Figure 42 Main Effects Plot for Simple Payback – down payment, BTU value, and loan term have the strongest influence on simple payback

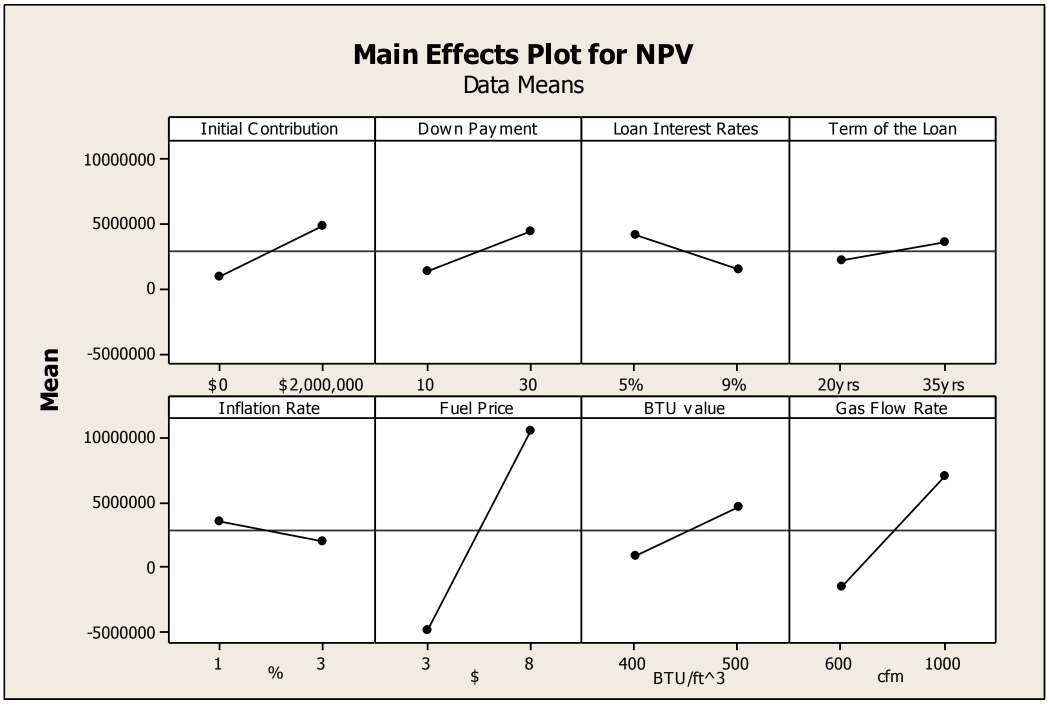


Figure 43 Main Effects Plot for NPV - Fuel price influences NPV the most. The other factors appear to have a statistically equal significance on the NPV value.

Calculator

One deliverable from this project was to provide BCSWMD with the ability to quickly calculate cost criteria for the Jonesville site. The calculator allows BCSWMD the ability to run a simulation run for any of the different scenarios outlined in the report. Figure 44 and 45 shows screenshots of the excel calculator. Note that random values were inserted to ensure the calculator was working properly.

Inputs				
Line Item	**Amount**	**Unit**	**Description**	**Block**
Initial Infrastructure Costs	$100,000.00	$	Piping and Well System	Initial Costs
Initial Donations	$5,000.00	$	Funds from outside sources	
Initial Engine Costs	$5,000.00	$	Total cost of engines	
Grid Infrastructure Costs	$5,000.00	$	Development of Grid for Applications	
Down Payment prior to Loan	$50,000.00	$	Amount paid that is not on loan	Loan Information
Loan Interest Rate	$0.05	%	Interest Rate on Loan	
Loan Period	$40.00	years	Loan Life	
Operation and Maintenance (Total)	$400.00	$	Maintenance of piping and equipment per year	Annual Costs
kw generated by engine	$1,000.00	kW	Max intended power output of engine based on available gas flow	Engine Information
Engine Utilization	$0.75	%	Uptime of engine and demand from grid: 1 = 100%	
kW rate	$0.06	cents/kWh	Given from utility company	Market Information
kW incentives	$0.02	cents/kWh	Government subsidies that raise revenue from kW rate	
Market Inflation Rate	$0.04	%	Predicted inflation rate for Present Worth/NPV calculation	

Outputs			
Item	**Amount**	**Unit**	**Description**
Loan Payment	($3,205)	$	Assuming Equal Total Payments
Annual Cash Flow	$1,579	$	Total Revenue - Loan Payment -
Simple Payback (Initial Down Payment)	31.67	Years	Initial Downpayment/Annual Cash Flow
Simple Payback Period	66.51	Years	Initial Costs/Annual Cash Flow
NPV	($18,753)	$	NPV calculated based on Loan

Figure 44 Calculator for Power Generation

Inputs				
Line Item	**Amount**	**Unit**	**Description**	**Block**
Initial Infrastructure Costs	$ 100,000.00	$	Piping and Well System	Initial Costs
Initial Donations	$ 5,000.00	$	Funds from outside sources	
Initial Cleaning Station Cost	$ 5,000.00	$	Total cost of engines	
Down Payment prior to Loan	$ 50,000.00	$	Amount paid that is not on loan	
Loan Interest Rate	5%	%	Interest Rate on Loan	Loan Information
Loan Period	20	years	Loan Life	
Operation and Maintenance (Direct Use)	200	$	Maintenance of piping and equipment per year	
Operation and Maintenance (Fuel	$ 400.00	$	Maintenance of piping and equipment per year	
Fuel Rate	1000	cfm	Max intended power output of engine based on available gas flow	Annual Costs
BTU Content	450.00	BTU/ft^3	Uptime of engine and demand from grid: 1 = 100%	Engine Information
Fuel Revenue (Direct Use)	$ 5.00	$/MMBTU	Given from utility company	
Fuel Revenue (Fuel Station)	$ 6.00	$/MMBTU	Government subsidies that raise revenue from kW rate	Market Information
Market Inflation Rate	4.00%	%	Predicted inflation rate for Present Worth/NPV calculation	

Direct Piping Outputs			
Item	**Amount**	**Unit**	**Description**
Loan Payment (Direct Piping)	($3,611)	$	Assuming Equal Total Payments
Annual Cash Flow	$1,162,589	$	Total Revenue - Loan Payment - O&M costs
Simple Payback (Initial Downpayment)	0.04	Years	Initial Downpayment/Annual Cash Flow
Simple Payback (Project)	0.08	Years	Initial Infrastructure Costs/Annual Cash Flow
NPV	$15,749,965	$	NPV calculated based on Loan

Fuel Station Outputs			
Item	**Amount**	**Unit**	**Description**
Loan Payment (Direct Piping)	($4,012)	$	Assuming Equal Total Payments
Annual Cash Flow	$1,395,268	$	Total Revenue - Loan Payment - O&M costs
Simple Payback Period	0.04	Years	Initial Downpayment/Annual Cash Flow
Simple Payback Period	0.07	Years	Initial Infrastructure Costs/Annual Cash Flow
NPV	$17,388,116	$	NPV calculated based on Loan

Figure 45 Calculator for Direct Use Applications

Comparison Table

In order to accurately compare the different scenarios, the values of each scenario for each metric were placed in a comparison table. A screen shot of the table is shown in figures 46 and 47.

Metric		Concepts (Jonesville Site)			
		Power Generation (1 stage)	Power Generation (2 stages)	Direct Gas - Sell to Utility	Direct Gas - Fueling Station
Project Description	N/A	Use landfill gas to power QSK91 engine and hook up to utility to sell electricity. This would occur once landfill has been completely capped	Use landfill gas to power QSK60 engines and hook up to utility to sell electricity. This would occur in two stages: when half the landfill is capped and the last half of the landfill is capped	Use landfill gas and sell to a utility company such as Vectren. This would occur after landfill has been completely capped	Clean landfill gas and use natural gas to power LNG trucks. This would occur after landfill has been completely capped
Project Life	Time to landfill to be capped (yrs)	40	29	40	40
	Time from contract approval to gas utilization (yrs)	5	5	2	3
	Highest Annual Cash Flow Achievable ($)	442,894	886,265	2,279,965	1,516,948
	Project Payback period (best possible in years)	17	8.18	2.59	4.84
Capital Costs ($)	Total	7,396,315	8,146,315	6,146,315	7,546,315
	Infrastructure	6,146,315	6,146,315	6,146,315	6,146,315
	Engine	750,000	1,000,000	0	1,200,000
	Other (Grid or Purifying equipment)	500,000	500,000	0	0
	O&M cost	315,000	432,000	72,000	108,000
	Community partner engagement	Duke Energy; Hoosier Energy; Cummins; Third Party Co-Gen; City of Columbus	Duke Energy ;Hoosier Energy;Cummins;Third Party Co-Gen; City of Columbus	Vectren Energy;NK Aluminum;City of Columbus	Vectren Energy; City of Columbus;Cummins (On-highway gas focus group);Department of Transportation
Physical Gas needs	Amount of gas needed before project start (ft^3/min)	800	400	800	800
	Total % of Available gas	60%	80%	85%	85%
	Cleaning required	No	No	Yes	Yes

Figure 46 Jonesville Comparison Table

Metric		Concepts (Petersville Site)					
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Project Description		Engine supplies electricity for kiln and glass blowing ovens. Exhaust gas used to heat greenhouse during winter months. During summer months exhaust gas can be used in kiln and glass blowing	Engine supplies electricity for kiln and glass blowing ovens. Exhaust gas used to heat greenhouse during winter months. During summer months exhaust gas can be used in kiln and glass blowing	Engine supplies electricity to green house. Exhaust gas used to heat greenhouse during winter months	Natural gas is sent to the cabins to heat during winter. During summer, gas is flared. Cabins can be used as a school camp/field trip place throughout the year	Engine testing site using a mid range gas compression product for testing purposes. Motor driven by the engine powers electrical needs during operation. Solar panels store energy into battery that powers cell at start	Current operation
Project Life (years)	Time to landfill to be capped	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Time from contract approval to gas utilization	4	[illegible]	3.5	[illegible]	[illegible]	[illegible]
	Likelihood of being funded over various project stages	High	High	Med	Med	Low	None
Capital Cost ($)	Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Infrastructure	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Engine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Green House, Glass blowing, Cabin, Education Center	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Other	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	# of community partners engaged in project	IUPUI Ag program; Art District; Farmer's Market; Cummins	IUPUI Ag program; Art District; Farmer's Market; Cummins	IUPUI Ag program; Farmer's Market; Cummins	IUPUI Ag program; [illegible] County School District; Cummins; Boy Scouts; Girl Scouts	Cummins	None
Physical gas needs	Amount of gas needed before project start (ft^3/year)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Total % of Available gas used	All year	All year	Winter months only	Winter months only	All year	All year

Figure 47 Petersville Comparison Table

Ranking

After the comparison table was complete, the team used a C&E ranking matrix to compare all the concepts using the metrics & metric weights from the QFD. Figures 48 and 49 show the tool used and tables 8 and 9 have the final values for each project.

Cause and Effect
Matrix: (Concept Selection)

C&E Correlation Rankings:
1 = Drastically worse
4 = Majorly worse
7 = Significantly worse than the best
10 = Performs best

Customer: BCSWMD-Petersville		Rating of Importance to Customer (low 1- high 10)	5	8	10	3	1	9	8	
			1	2	3	4	5	6		
	Process Sub Step (if applicable)	Inputs	Earliest project to start	Initial Capital Investment	# of community partners engaged in project	Initial Gas placement to start project	Total % of Available Gas Used	Likelihood of being funded over various project stages	Ease in achieving project cohesion between multiple groups	Total
1		Combined community (engine, green house, Kiln, veggie patch) with upgraded piping	4	1	10	1	7	7	1	209
2		Combined community (engine, green house, Kiln, veggie patch) with current piping	4	4	10	4	7	7	1	242
3		Agricultural focus usage	7	7	4	4	4	4	4	215
4		Cabin & Recyling Education Center	7	4	7	4	4	4	4	221
5		Field Test Pad	7	7	4	4	10	1	4	194
6		Continuous flaring	10	10	1	7	10	1	10	260
Total			195	264	360	72	42	216		

Figure 48 Petersville Ranking Matrix

Cause and Effect
Matrix: (Concept Selection)

C&E Correlation Rankings:
1 = Drastically worse
4 = Majorly worse
7 = Significantly worse than the best
10 = Performs best

Customer: BCSWMD-Jonesville		Rating of Importance to Customer (low 1- high 10)	6	9	8	1	5	10	3	8	8	
			1	2	3	4	5	6	7	8	9	
	Process Sub Step (if applicable)	Inputs	Earliest project to start	Initial Capital Investment	# of community partners engaged in project	Initial Gas placement needed to start project	Total % of Available Gas Used	Likelihood of being funded over various project stages	Time for project to start using gas	Shortest Payback Period	Highest Potential Annual Cash Flow	Total
1		Power Generation (1 stage)	1	7	10	4	1	7	4	1	1	256
2		Power Generation (2 stages)	9	4	10	7	4	7	4	4	4	343
3		Direct Gas - Sell to Utility	7	10	4	4	7	10	7	10	10	484
4		Direct Gas - Fueling Station	4	7	7	4	7	4	7	7	7	355
Total			126	252	248	19	95	280	66	176	176	

Figure 49 Jonesville Ranking Matrix

Table 8 Jonesville Final Ranking

Concept	Final Value
Direct Gas – Sell to Utility	484
Direct Gas – Fueling Station	355
Power Generation (2 stages)	343
Power Generation (1 stage)	256

The ranking tool helped determine that selling the fuel directly to a utility company would be the best project to select. The results are discussed more in the “Next Steps” section.

Table 9 Petersville Final Ranking

Concept	Final Value
Continuous flaring	260
Combined community (engine, green house, Kiln, veggie patch) with current piping	242
Cabin & Recycling Education Center	221
Agricultural focus usage	215
Combined community (engine, green house, Kiln, veggie patch) with upgraded piping	209
Field Test Pad	194

The ranking tool did not determine a clear winner for a best project. While continuing to flare the gas has the highest value, an argument could be made for the benefits of a combined community project outweighing the cost savings from continuous flaring.

Final Assessment

Petersville

This report serves as a quantitative guide to BCSWMD that the Petersville site could still serve as a community project. The biggest barrier identified through this project is the upfront building costs. The author believes that one funding source will be unlikely to support all the upfront costs for this project; however, a combined community effort with BCSWMD, the Cummins foundation, Ivy Tech, local farmers, and venture capitalist would be able to alleviate the cost of doing any of the listed projects.

It is the opinion of the author that the next steps for the Petersville site should be the following:

- Solicit further interest from the community on willingness to participate in the project from a monetary and man power stand point.
- Gain the support of the Bartholomew County government to have a greater success rate of developing the project
- Work with the Cummins CSS-CIT team by investigating potential grants and writing grant proposals for the final project selected

Jonesville

This report serves as a reference to the future owner of the Jonesville landfill site. Since the site is large enough to provide more than 500 cfm of gas, the landfill has been of interest to many large parties such as Duke Energy, Hoosier Energy, Enkei Aluminum, and Cummins Inc. The report has made sample flow models that depict each of these large parties' interest and then puts a financial model to each flow model. From the results of the study, the 6S team recommends using a direct gas type application where BCSWMD sells their landfill gas to a third party utility such as Vectren. This is based on the fuel price being greater than the infrastructure and maintenance cost of using a power generation unit; however, if enough investment was placed into the power generation unit to offset initial costs or if the revenue source goes up for the model, then the power generation model would be the best application.

It is the opinion of the author that the next steps for the Jonesville site be the following:

- Wait for landfill to be completely capped in the next 20-40 years
- Use the calculator at the point in time when the landfill is half capped to explore what options look best at that point in time

Conclusion

In conclusion, the 6S landfill utilization and feasibility project stayed in scope and has provided BCSWMD tools to discern which projects are feasible. The project has also provided the Cummins CIT team more knowledge about the surrounding community. More specifically, the Petersville site would be a valuable site to establish a community partnership with multiple entities. The site could eventually be comparable to the NC Energy Exchange site. In addition to the Petersville site, studying the Jonesville site has enabled BCSWMD to benefit from a financial model that is able to vary many parameters for future estimates. Overall, the author and team believe this was a successful project.

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Appendix

Landfill Operator Interview

Landfill Geography
1) What is the landfill size (sq. ft, acre), tonnage, and age? About 23 acres, was a legal landfill, Things have been dumped since late 1800 (bricks were dumped in there)
2) Does the landfill have any type of special geographical features? Contoured landfill (a little bit rolling). Can see downtown Columbus, OH (nice feature). Can see buildings pretty far down. Along one side is a stream and woods (which have been made into a city park).
3) Are there any expansion plans for the landfill? No because closed. EPA has signed off that it is a fully remediated landfill.

Gas Composition
1) What is the gas composition of the landfill? Took methane off of it for the last 20 years (pipeline that took it to a nearby large business). But now there is not enough methane to merit using the pipeline (50%). The pipes were not taken out b/c hoping they could use them.
2) Has the landfill gas composition changed over time? If so, how? Methane content is the same however, the amount decreases over time. Pretty much starting to remediate, the methane content sank because of construction. They were putting irrigation pumps and the guys putting the irrigation pipes cut through methane pipes but then corrected.
3) How often does gas sampling occur? On average, how many samples are taken? Lately, have taken monthly gas samples (to see the content). In the past, the company that was responsible for landfill didn't do it very much at all.
4) How do any future plans for the landfill affect the quality of the gas? There is enough gas that we flare the landfill. Methane pump that helps to flare it off. Pay electric company about 500 a month for flaring.

Gas Utilization
1) Are there any current utilization methods of the landfill gas? If so, how is the gas collected and is it treated/filtered? Pretty sure it was not being treated but was being used as raw gas to large building.

2) Where there any tax credits/incentives that made utilization of the landfill easier? Pretty sure no tax incentives. Went more than a mile long. Went to a building that had around 5k building.
3) What was the most difficult thing to overcome in the process? (utilizing landfill, maintenance, etc) Hardest part is the pipes. Recently had to replace the flares. Really not a problem because certainly lived useful life. Flaring takes very little maintenance. Sometimes it goes out.
4) What method(s) were/was not chosen and why? Not at the end Took about $6 M dollars for golf course. May be low (was done with a whole series of grants). It is being funded by the county now (has been for over 30 years). We are leasing it to company to do the golf course. Basically will break even over 30 years. Purpose of redoing it was b/c a lot of vacant land around it would be better to convert to golf course.
5) Was there previous infrastructure at the landfill or did the infrastructure need to be developed?

Pipes were put in place a long time ago. Pipes helped over 30 years. Had to replace all pipes for landfill.

Landfill is wet landfill; 53 acres is the landfill size

Gordon Parish Interview

Working back with them back in 07 or 09 (environmental something core). At the time they had a model where they would see small landfills with opportunities for carbon build up.

Did a little leg work and research and bring some landfills in the Ohio, Kentucky, and Indiana area. Mostly closed facilities. 300-400 cfm range. Less than a MW potential (so area next to the site). Pottery shop or green house next door, 50-60 cfm type deals.

These guys were convinced in doing the carbon trading to generate revenue. Ultimately was hoping that once we knew how we could channel gas, they could generate power.

Travis Murphy IDEM – encourage gas to energy use for the smaller and mid-size facilities. Went to Indiana's department of energy. Not there anymore, interestingly enough went to Indianapolis and attended a conference with EPA and LMOP. Obstacles, Jim Murray, did not see the value of taking the risk of doing something to the site that would make them against IDEM.

Attended a workshop where IDEM tried to facilitate energy development

There are a few developers that are small enough that can make a play with it (especially if they can get their)

One developer (combined heat and power cycle)- Two sites in Ohio (Co Generation consultants in Walled Lake Michigan)

They priced out CAT/GE Jenbacher (he could probably get a lot of play if we can get Cummins involved)

Seemed like something really close was going to get done. We had a meeting with county commissioners and Jim seemed favored into it. It seemed nice but they didn't want to risk money with poking holes in the landfill and risking some other trouble.

If something is done with a team, could recap it if something fails. But a lot of communities seem to be hesitant with the risk.

70,000 tons per year - About close to a MW of power

Projected it going out to 2020 or 2030

Generally, has advised clients or potential clients with closed facilities and they are spending a certain amount of money for O&M, explicit gas monitoring and leachate disposal. Bring in developers that will pay for everything and share some percentage of the revenue. Then Bartholomew County doesn't have to fund the money so it helps with the cost.

May not know how well they will produce. If Bartholomew County

$600,000 for collection

Title IV compliance forces this to happen

$25,000 per acre to meet compliance to get gas

50 acre site ($1 M)

Could invest it all (team of people together, then cost spreads out)

About 2/3 of landfill gas projects are electricity. Once you are on the grid, the grid is always there. About a third of time is direct use (use natural gas directly). Nice medium BTU fuel. More of a community type deal.

Critical people that we should be involved with (say Power generation):

a) Hoosier Energy (or Duke Energy). Would be more than happy to take power but not willing to spend a whole lot of time to investing in the infrastructure. They do like 24-7 nature of landfill gas. Will be running 90% to 95% capacity. (So maybe 5 or 6 players in this).
b) Co generation consultants have been talking with GM. The GM has a program in place where they are trying to be greener and being more renewable. Popular with Honda in Columbus, OH area…. So maybe translate to Toyota? Electric generation would be useful with co-generation. Electric power on the grid, you can basically earmark where the support and funding goes

2 MW of electricity from 1000 scfm facility… developers are interested but the sites were flaring gas due to electric utility. They held all the cards b/c of pricing and things like that.

Grant opportunities? Alternative funding sources? On the waste water side, encouraging co-generation plants with water side. Matching funds for doing co-generation or microturbines

Microturbines for small side (25-50 or 55 kW) per unit

May be a little more risky but could get more money…

Safest thing but non glamorous (put an IC engine and then put it on the grid). Biggest hard block is the hoops getting into the grid. Not much downside.

CNG/LNG fuels… Didn't want to do it before because of high BTU need (unless making 1500 cfm)… but now vehicles would like more. Could be demand for that if we have any CNG goals or looking to turn city cars into that. At old company, he was VP and he ran renewable energy. Solar energy, wind, CNG…

Going through US EPA LMOP … 2500 bucks / kW of capacity (1 MW project will be 2 to 2.5 $)

Gas piping project…. Medium BTU boiler and not much clean up. A lot less capital initially and rule of thumbs will be emailed later. As is, 50% natural gas type of niche, the cost is relatively low because all you need is a blower compressor (however much it takes to get that going).

1 MW IC engine…. $750k by itself to $1M

Watch out for siloxanes and hydrogen sulfides that will need to be cleaned out before using.. but at the same time you can say 52% methane and nothing else in it. Then sell the idea to developers.

Average house uses 2 kWhr which would equate to 500 homes for 1 MW

Ralph Slone

NOx Tech – product that treats exhaust from IC engines

Exhaust has siloxanes that can't be burned and not economical… Don't use catalyst for unburned

Patented combustion process that can reduce from 10-8 ppm range of NOx, 40-30 ppm CO, and <5 ppm HC – all for landfill gas

Located in San Waukee county, Woodville treat exhaust from methane gases in waste treatment plant. Working with Eastern Municipal. Water Company located in Perris, California, Riverside Marine Valley

So the reason I would be helpful is during gas production. The majority of gas on market is from shale gas which precludes cleaning gas for pipeline. The gasses are typically CO_2, water, Siloxanes, and H_2S (making clean gas is too expensive for the current price comparison of diesel to gas)

If the gas is used in a boiler or plant, there is a capital investment involved. Minimal clean up to pipe and run gas to a NG engine. IC NG engines use gas but need to have water taken out. This worked well with a company out of Cleveland. Typically the process includes drill wells that are plumbed with a manifold and are driven by pumps and a condenser.

One potential group to reach out to is Waste Management Fortestar which is a capital investment group who bids to own contract rights to the landfill.

Landfill gas usually has a composition of 40% Methane and 35-40% CO_2 which leads to fuel quality ranging between 400 BTU/ft^3 to 500 BTU/ft^3

Going into power generation application is modular but not cost effective because the size of the switch gear to connect to the grid is tied to engine used.

The biggest issue is the Siloxanes which stay in the gas composition till 1800 deg F. It behaves a lot like slag in a boiler. With such a high melting point in a gas to gas heat exchanger most likely coating on tubes and efficiency goes down quickly.

Speculation: If they use in a boiler, clean the Siloxanes and should be good for a boiler. Perhaps use the gas with Aluminum Enkei who could benefit up by having up to 40% of their gas needs provided by the landfill year round.

Doug Day Email:

" Doug Day asked that I follow up with you regarding Duke Energy's interest in obtaining electricity from purchasing electricity or helping with infrastructure cost or a combination of both in regards to the BCSWMD Landfill gas project.

According to the IURC, Indiana Utility Regulatory Commission, regulations we cannot donate infrastructure as doing so would be done at the cost of other ratepayers which we cannot do.

You could consider generating electricity back through our existing Rider #50, Parallel Operations and receive the noted kwh energy cost credit. The other option would be to use the generated energy within your own operations and look for other process uses . Under the information in Rider #50, there can be some major costs to upgrade the Duke Energy Indiana system to be able to handle the power sent back into our system. All system protection costs would have to be paid by the customer under Rider # 50. Our system was not designed to receive power back on the grid and when receiving power we have to ensure the integrity of the system as well as the service to other customers.

Paralleling operations and reviewing the total system operations is a tedious process and is not guaranteed to always be the best solution. We would suggest that the noted Riders and agreements be reviewed first and then we can start to determine what information will be needed to be tied down to see if this is a potential solution for both parties."

NC Exchange Project (Source Unknown)

The Yancey/Mitchell Joint County Landfill was opened in 1972 in an abandoned mica mine and closed in 1994. The average population of these two counties during this period was approximately 28,000. The economy of the area was largely agricultural and forestry based. Some manufacturing was present during this time in the textile, furniture, and light manufacturing. The landfill is about 6 acres in size with a maximum depth of 100 feet. An estimated 300,000 tons of waste are buried in this landfill and covered by a 3-5 foot clay cap.

6.2 LANDFILL GAS COLLECTION SYSTEM

The landfill gas collection was activated on April 22, 1999. The system includes 8 vertical wells which consist of 4" diameter HDPE plastic pipe and a 24" diameter gravel envelope. Wells range from 30-85 feet deep. The system also contains 2 horizontal wells just below the landfill cap, a condensate collection system and a 5 horse-power blower-flare skid capable of handling approximately 90 cubic feet per minute of landfill gas. The landfill gas currently being collected is about 45-50 cubic feet per minute. The graph (attachment 1) shows the expected landfill gas generation and collection through 2015. It is important to note that the US Environmental Protection Agencies Landfill Methane Outreach Program uses a threshold level of 1 million tons of waste in place as the level of economic feasibility for landfill gas projects. Our landfill is one-third that size.

6.3 GLASS AND POTTERY BUSINESS INCUBATOR

One of the two major features of the EnergyXchange Renewable Energy Center is a glass and pottery business incubator. This business incubator consists of four buildings. Each of these buildings is a 3,000 square foot prefabricated arch type metal building. These buildings are heated by radiant floor heat and direct waste heat from landfill gas fueled boilers. The glass studio houses two glass blowing tenants. Equipment includes two pot furnaces and a glory hole which are operated at 2,300 degrees Fahrenheit, 24 hours a day, 365 days per year. The pottery studio houses four potters. There are two electric kilns, but also one large landfill gas fired kiln for firing these ceramics. In addition to the studios, the business incubator also includes a business and visitor center which includes a meeting room and a business center which includes individual office space for each artist and access to business machines including fax machine, computers with internet access, copy machine, etc. The fourth building is a gallery where visitors may view, select, and buy glass and pottery produced by the resident artists.

6.4 GREENHOUSE COMPLEX

The original home of Project Branch Out includes four 32x100 foot hoop style greenhouses with a double flexible plastic covering. Three of the greenhouses are production greenhouses where native shrubbery seedlings are produced from locally gathered seed. These greenhouses are staffed by a nursery manager and a part-time assistant as well as 2 high school apprentices. A fourth greenhouse is used for a demonstration of hydroponics – a symbiotic combination of indoor aquaculture and hydroponic plant production. These greenhouses are heated by two natural gas boilers which were factory customized to burn 500 btu/cubic foot landfill gas.