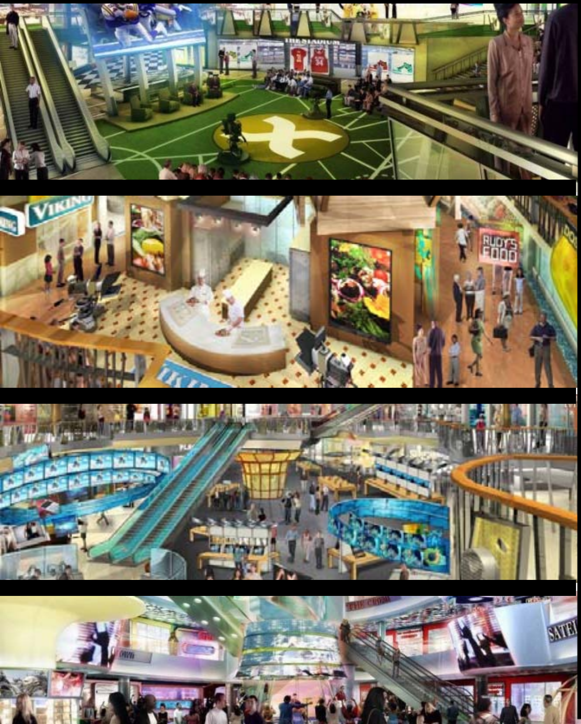
Jason M. Sambolt
Mechanical Option



From Liability to Asset:

The Use of Renewable Energy and Cogeneration

Xanadu Meadowlands Sports Complex Building A
East Rutherford, New Jersey

Existing Building Summary

Presentation Contents

Existing Building Summary

Presentation Contents


Existing I


Redesign


Ventilatio


Mechanical Redesign


Structura


Electrical


Conclusi

Building Abstract

- Located in East Rutherford, New Jersey
  - Current Meadowlands Sports Complex
- Owner: Colony Capital
- Architect: Rockwell Group
- Project Size
  - Total Complex: 2.5 Million Square Feet
  - Building A: 553,000 Square Feet
- Total Cost: $2 Billion
- Design-Bid-Build Contract
- Construction Dates
  - Start: June 2004
  - Scheduled Finish: November 2008

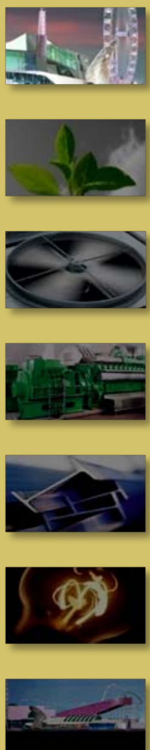
Existing Building Summary

Building Use

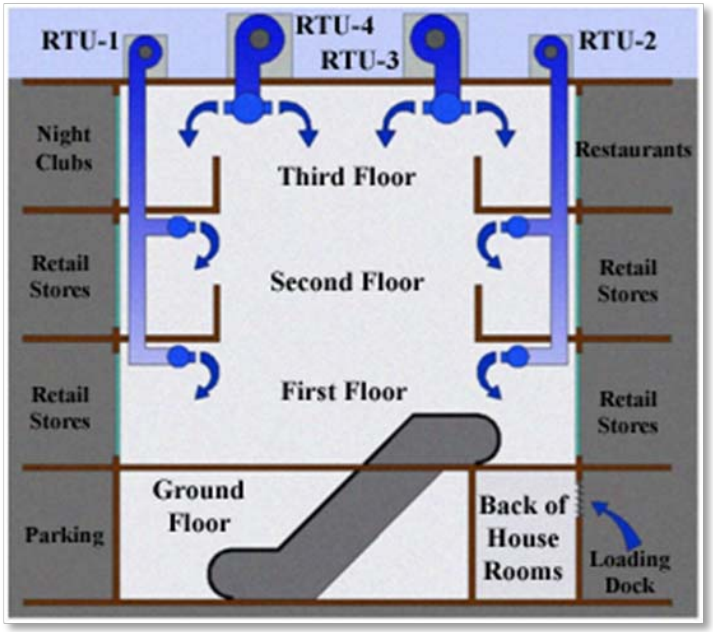
Retail Section
- 393,000 square feet leasable space
- Common area large three floor atrium
- Sports District
- Cabela's and Golfdom anchor stores

Indoor Ski Resort
- 160,000 square feet conditioned space
- Snowdome – First in North America
- Provides skiing conditions year round
- 190 foot main slope rise

Existing Building Summary



Existing Retail Mechanical System



Four Rooftop Direct Expansion Units

- CAV units serving common area atrium
- Electric Resistance Heating
- RTU 1 & 2
  - Serve 1st and 2nd floors
  - Both 38 tons and 16,100 cfm
- RTU 3 & 4
  - Serve 3rd floor
  - Both 78 tons 31,000 cfm
- Tenant spaces not in contract

Design Conditions

- 75°F daytime operation temperature
- Time clock controlled nighttime setback

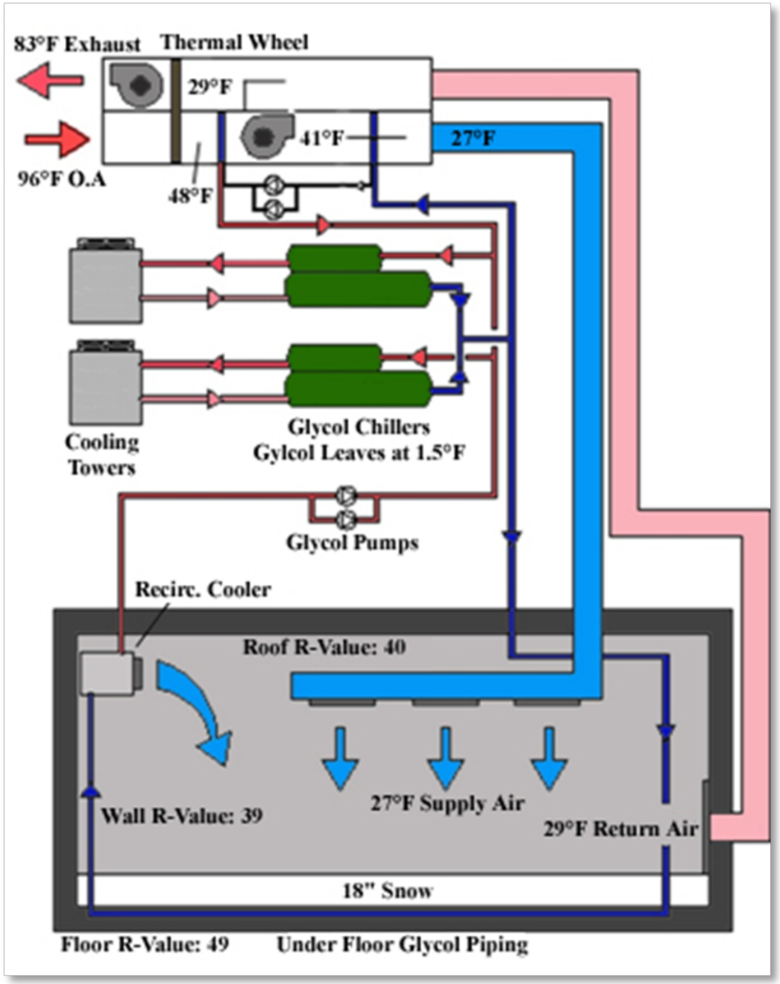
Existing Building Summary







Existing Snowdome Mechanical System



Two 222 Ton Centrifugal Chillers

- Electrically driven
- 1.5°F leaving glycol serves
  - AHU Coils
  - Under floor piping matrix
  - Recirculation coolers
  - Snow making guns

Air Handling Unit

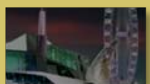
- 30,000 cfm supplied at 27°F
- 50% outside air

Design Conditions

- 30°F daytime operation
- 24°F nighttime snowmaking
- 100% relative humidity

Redesign Goals

Presentation Contents



Existing Building Summary

Redes

Ventilation Redesign

Mecha

Structural Impact

Electr

Conclusions

The New York Times

Metro Briefing New Jersey: Trenton: Suit Over Sports Complex

Ronald Smothers (NYT). Compiled by Anthony Ramirez. New York Times. (Late Edition (East C

The New York Times

Party Promotes Huge Meadowlands Project as Critics Raise Concerns

Ronald Smothers. New York Times. (Late Edition (East Coast)). New York, N.Y.: Oct 6, 2004. pg. B.5

The New York Times

Huge Meadowlands Project May Be Delayed by Lawsuit

Ronald Smothers. New York Times. (Late Edition (East Coast)). New York, N.Y.: Mar 28, 2003. p

The New York Times

Xanadu Moves Ahead, but With Asterisks

Ronald Smothers. New York Times. (Late Edition (East Coast)). New York, N.Y.: Aug 29, 2004. p

Address Current Liabilities

- Environmental
  - Lawsuit filed by four advocacy groups
  - Large amount of energy required
- Public Relations
  - Publicized lawsuit created negative publicity
  - Community questioning need of indoor skiing
- Economic
  - Lawsuits and financial uncertainties caused:
    - Long delays due to construction halts
    - $700 million in budget increase
  - Rising energy costs, increase in annual cost
- Health
  - Increase in local pollution
  - IAQ concerns of retail ventilation

Redesign Goals

Through the use of:

- Readily available renewable energy
- On-site energy production
- High efficiency equipment
- Taking advantage of typically wasted energy

The redesign will attempt to
turn a large liability into an asset for all.

Ventilation Redesign

Presentation Contents

Ventilation Redesign

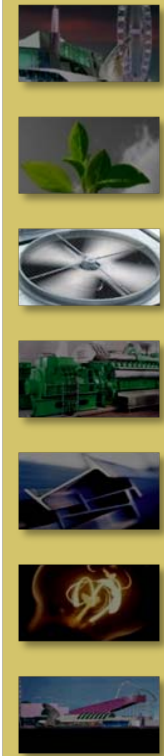
Current Design:

- Does not comply with ASHRAE Standard 62.1
- Highly over ventilated and under ventilated spaces areas
- Return plenums feet away from the supply (short circuiting)
- Only direct ventilation to the atrium, corridors used to transfer air to other spaces
- Naturally ventilated spaces directly adjacent to parking or loading dock

Redesign:

- Resizes rooftop units to meet localized floor demand
- Localized return grilles
- Provides direct ventilation to all spaces
- Supply and return duct designed at 0.06 and 0.08 inches per 100 feet respectively
- Introduced forced air ventilation to previously naturally ventilated spaces

Ventilation Redesign

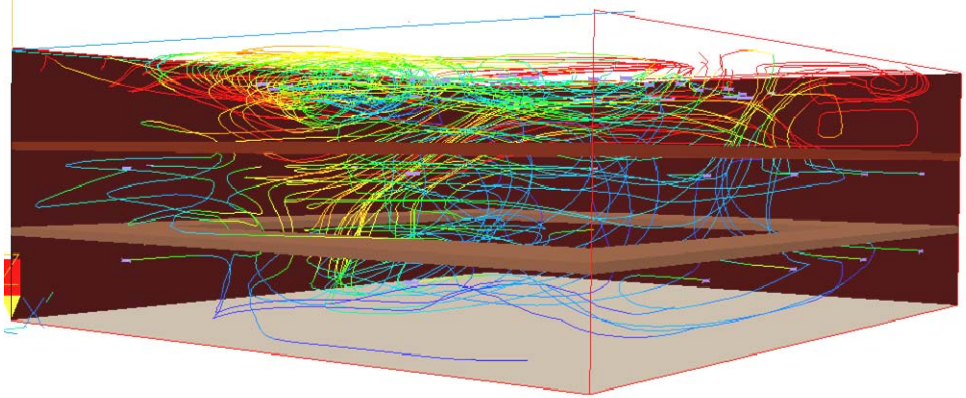


Computational Fluid Dynamics Winter Conditions Study

Trace dye injected into supply air stream

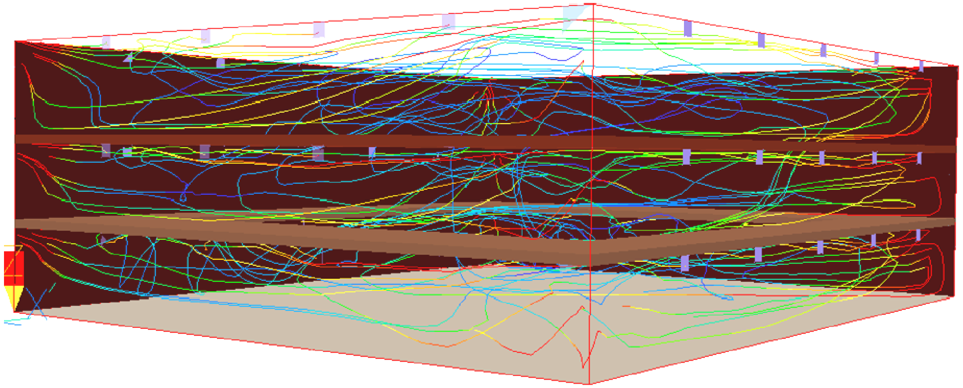
Existing: High Returns

- Short circuiting present
- Air tends to stay high



Redesign: Localized Returns

- Eliminates short circuiting
- Air tends to dissipate evenly



Ventilation Redesign







Results of Ventilation System Redesign

Ventilation System Comparison Summary			
Item	Existing System	Redesign System	Difference
Total Length Supply Duct (ft)	2,423	3,450	1,027
Total Length Return Duct (ft)	0	2,294	2,294
Total Weight of Ductwork (lbs)	23,612	40,661	17,049
Total Cost	$1,013,193	$2,077,902	$1,064,709

- Introduce 3,321 feet and 17,050 lbs of new ductwork
- Price increase of nearly $1,064,709 in ductwork

Benefits

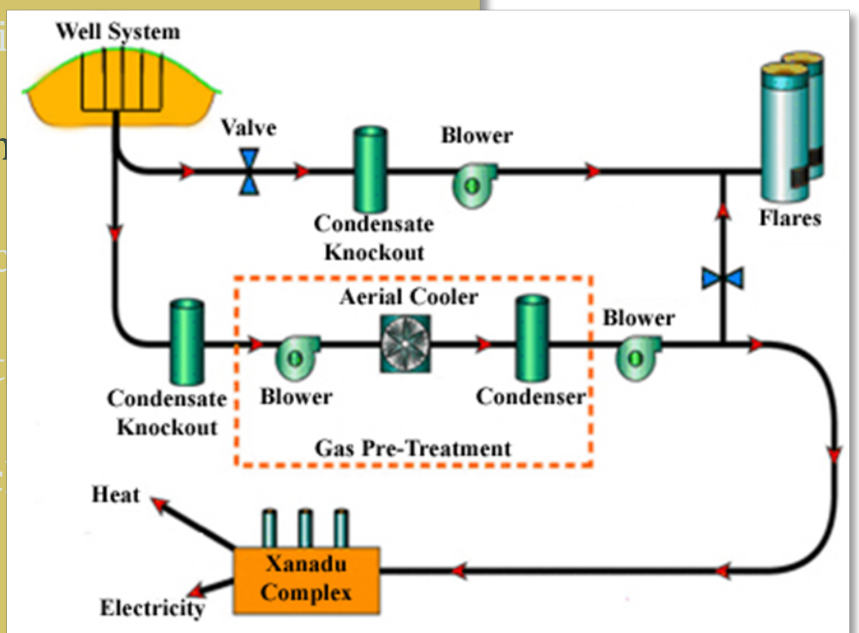
- Now compliant with ASHRAE Std. 62.1
- Improved indoor air quality
- Higher efficiency in the distribution of air resulting in:
  - Less energy required to power the fans
  - Less energy required to condition the air

Presentation Contents

Renewable Energy

Untapped source of energy in landfill gas collection

- Currently 424 landfill gas (LFG) collection projects operational
- Present in 42 states
- LFG collection produces 10 billion kilowatt-hours of electricity annually
- 50% methane, 49% carbon dioxide, and 1% non-methane



Collection Process

- Well drilled into landfill
- Moisture and particulates removed
- Treated gas piped to site
- Excess flared or sold

Mechanical Redesign

Local Landfill Gas Source

GROWS Inc. Landfill

- Located 3.5 miles from site
- Approximately 4,050,000 S.F. of fill

Typical LFG collection systems:

- Produce 0.344 SCF/(SF x day)

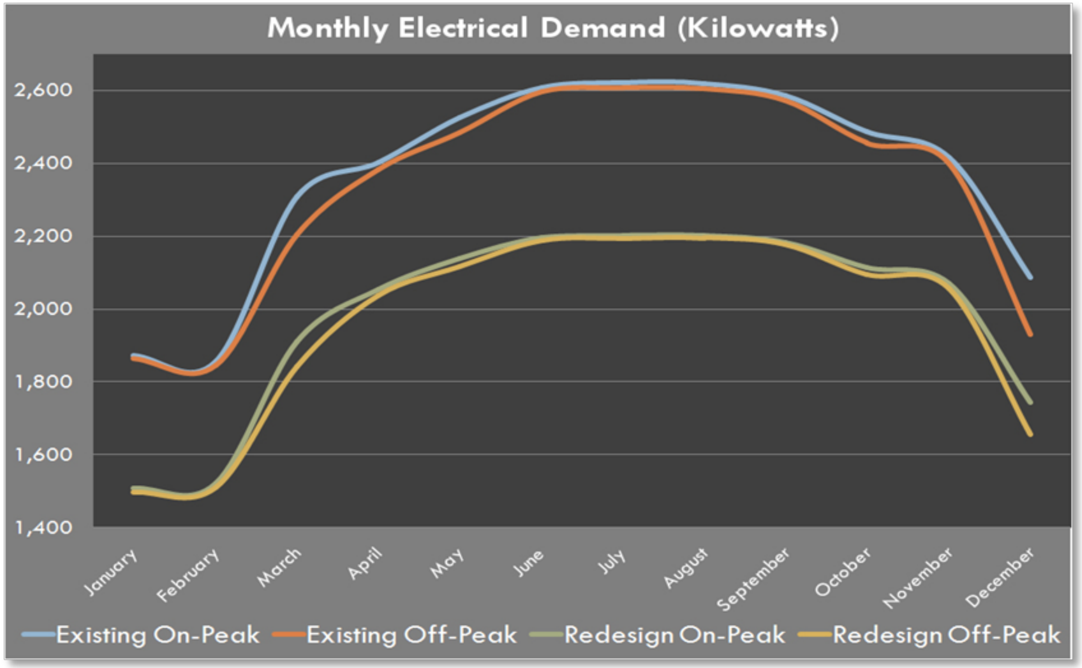
GROWS Inc. Landfill can provide:

- 58,000 SCF/hr or **1,645 Nm^3/hr** of treated landfill gas at a LHV of 5 kWh/Nm^3

Mechanical Redesign

Prime Mover

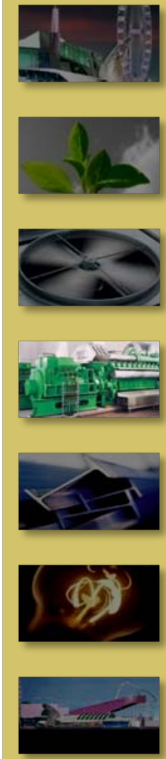
- Prime mover will produce electricity on site through combustion process
- In addition, can produce steam through the use of waste heat
- Can be sized to meet electrical demand or thermal loads



Based on the close on-peak and off-peak demand, system sized for electrical demand.

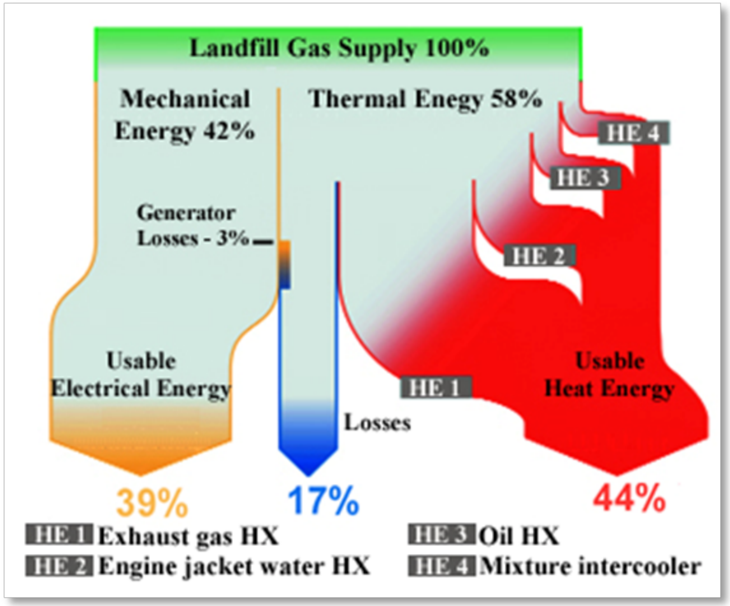
- Due to the retail nighttime set back and the snowmaking coinciding
- Will allow a single prime mover to meet demand all day long at peak efficiency

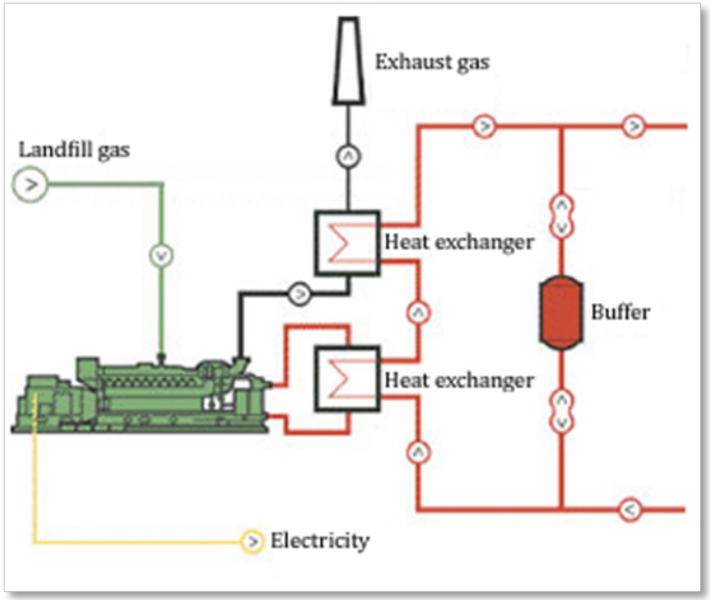
Mechanical Redesign



Prime Mover Selection

- With 25 years of landfill gas combustion experience, a GE engine is selected
- Based on the 2.2 Megawatt peak demand, a 2.4 MW capacity engine selected
- General Electric Jenbacher Engine Model JMS 620 GS-BL selected





- Designed specifically for landfill gas at a peak input of **1,241 Nm^3/hr**
- **2,433 kW** peak electricity produced
- **3,264 lb/hr** of medium pressure steam produced

Mechanical Redesign

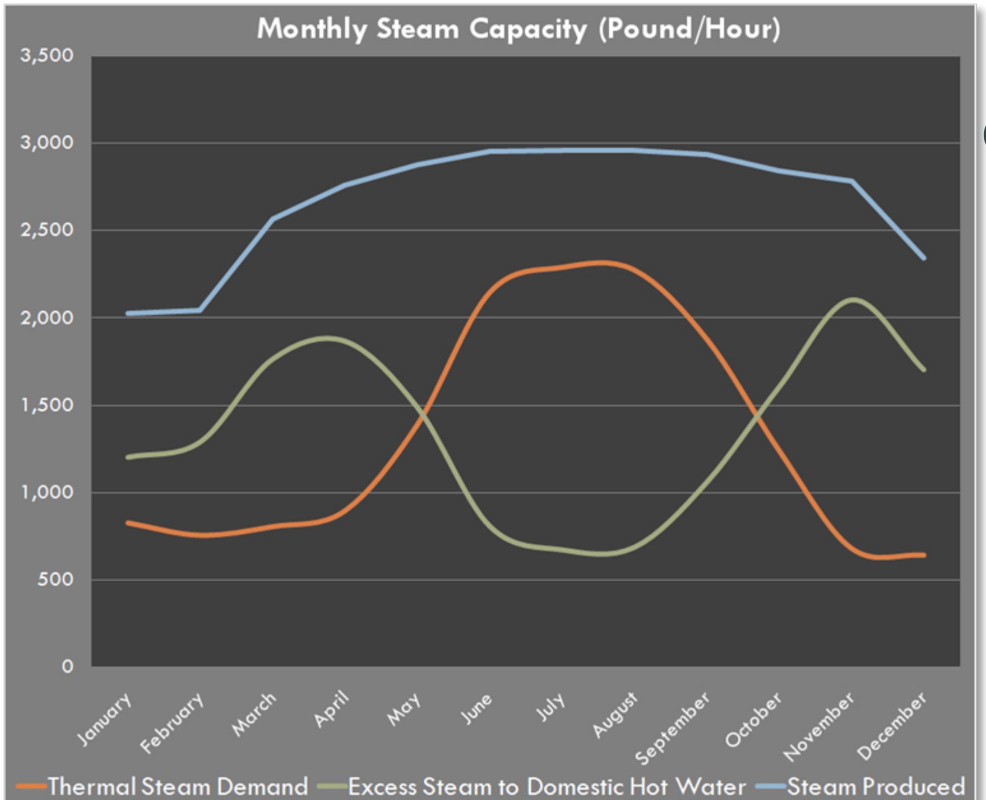






Steam Use – Absorption Chiller / Heater

- Steam from the prime mover can be used to meet retail thermal loads
- Based on energy simulations there is a peak cooling load of 267 tons
- A Carrier double-effect steam fired absorption chiller / heater is selected



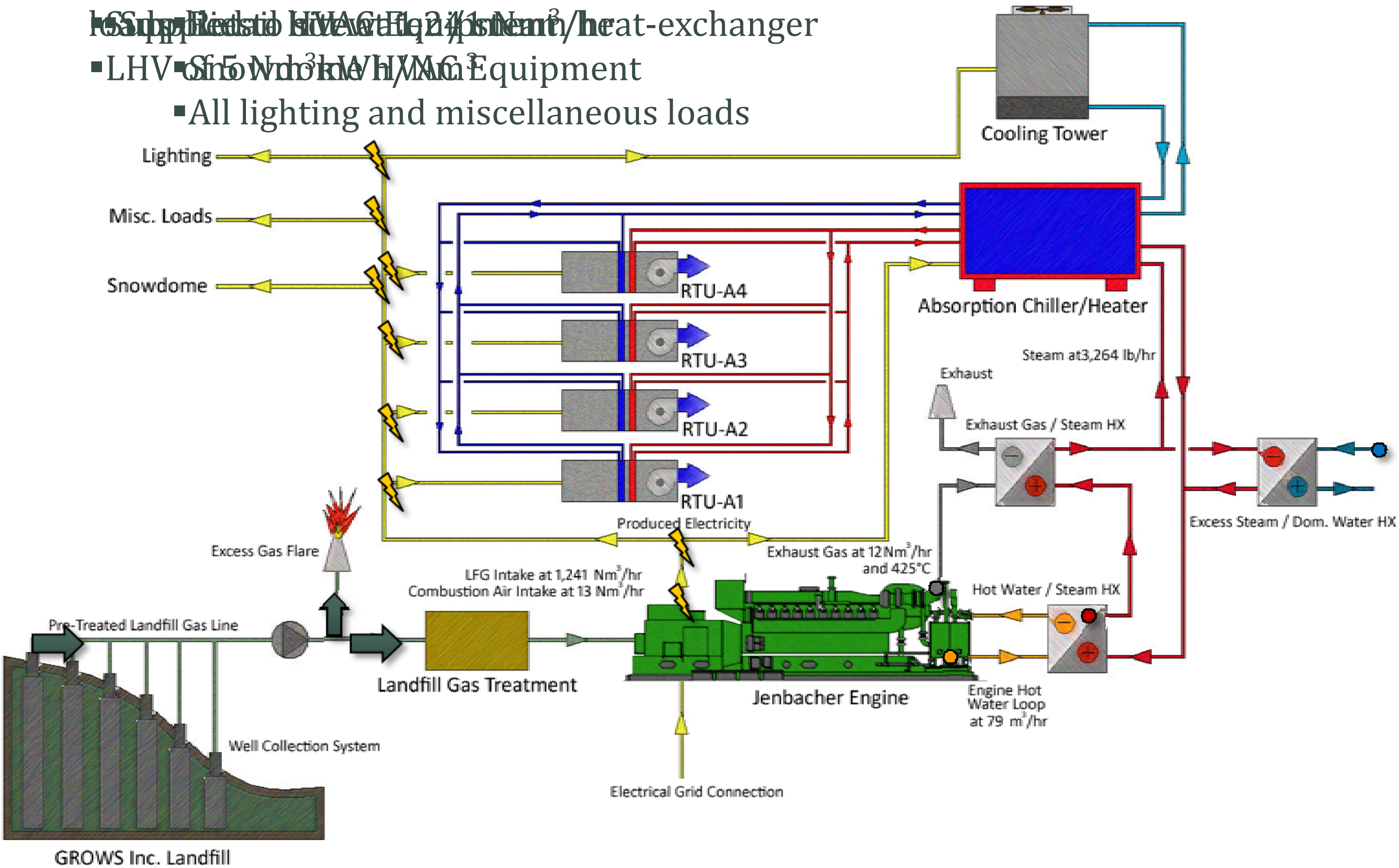
Carrier Model 16NK

- 294 ton cooling capacity
- 2,601 lbs/hr peak steam consumption
- Excess steam produced year round
- Excess used to heat DHW for entire complex through the use of addition HX

Mechanical Redesign

Total System Schematic

- ... consumed
- ... DHW heating
- ... heat-exchanger
- LHV of 5 kWh/Nm^3
  - Snowdome HVAC Equipment
  - All lighting and miscellaneous loads



Mechanical Redesign

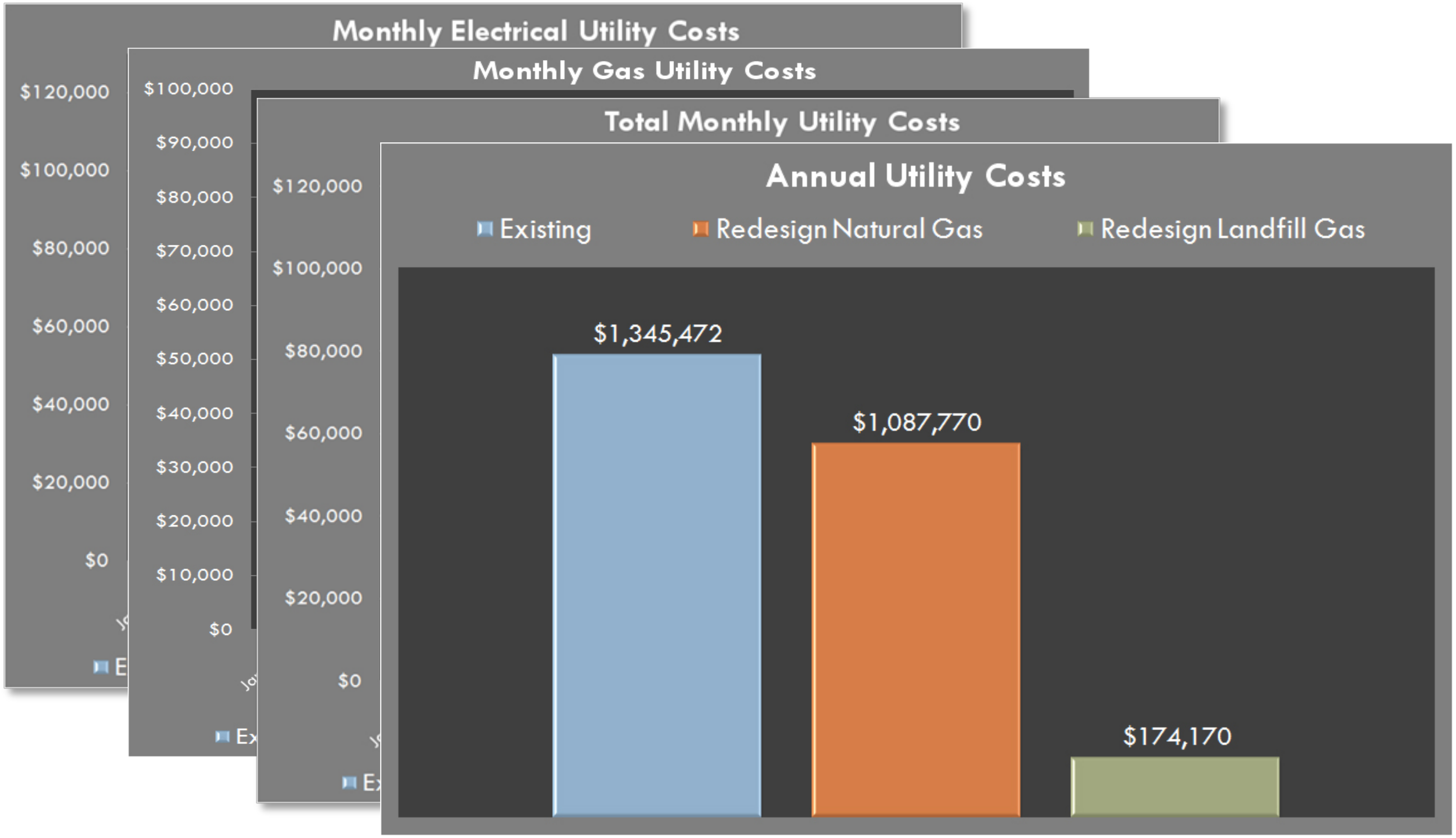






Economical Evaluation

- PSEG Power is the sites electrical and natural gas utility provider
- Actual rates used for analysis
- The existing system, the landfill gas system, and a natural gas system analyzed
- Average price of previous LFG contracts used, $0.35 per therm



Mechanical Redesign

Economical Evaluation







Mechanical System Redesign Economic Evaluation

	Existing	Redesign Natural Gas	Redesign Landfill Gas
Capital Costs			
Total	**$13,756,656**	**$15,977,494**	**$21,189,994**
Yearly Costs			
Grid Electricity	$1,345,472	$54,641	$54,641
Natural Gas	$0	$1,032,963	$0
Landfill Gas	$0	$0	$258,725
EPA 2005 Section 45 Credit	$0	$0	-$139,196
Maintenance	$83,517	$138,648	$231,079
Totals	**$1,428,990**	**$1,226,252**	**$405,249**
Economic Evaluation			
Payback Period	-	**8.4 Years**	**6.6 Years**
Total Utilities After 20 Years	$30,580,382	$25,260,787	$8,104,989
Total Savings After 20 Years	-	**$5,319,595**	**$22,475,393**

- Trends in utility rates used for 20 year analysis
- Capital cost of LFG system is almost $7.5 million more
- Payback period within 7 years
- Annual savings of approximately $1 million
- Over $22 million in savings over 20 years

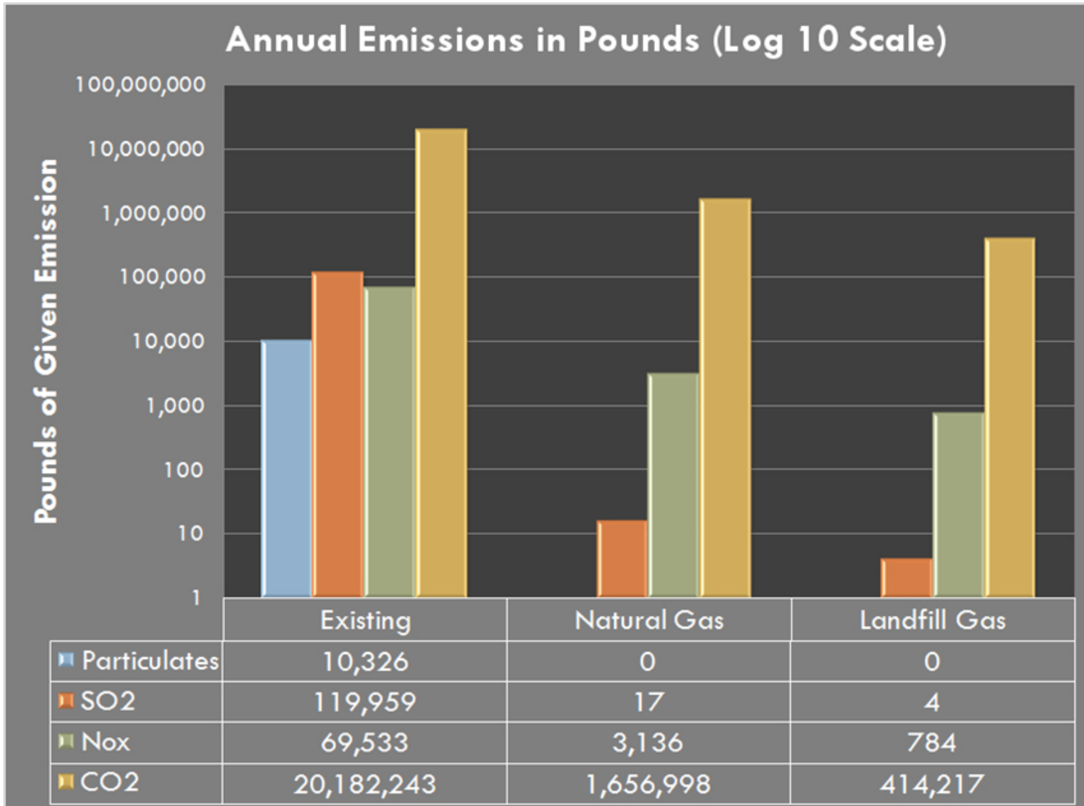
Mechanical Redesign







Environmental Evaluation



	Existing	Natural Gas	Landfill Gas
Particulates	10,326	0	0
SO2	119,959	17	4
Nox	69,533	3,136	784
CO2	20,182,243	1,656,998	414,217

Annually Equivalent To:

- Planting 26,000 acres of forests
- Preventing the use of 221,000 barrels of oil
- Removing the emissions from 18,200 vehicles
- Statistical Source: EPA

Structural Impact

Presentation Contents

New Gravity Loads

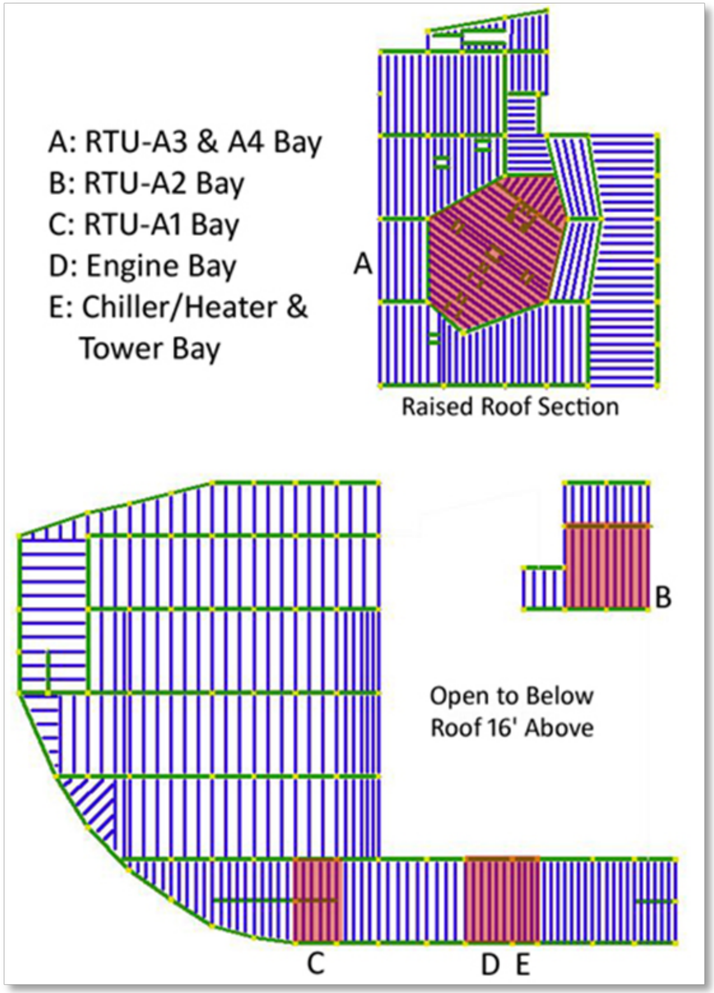
- All new mechanical equipment is placed on the roof

Equipment	Existing (lb)	Redesign (lb)	Difference (lb)
RTU-A1	16,000	18,000	2,000
RTU-A2	16,000	17,800	1,800
RTU-A3	17,000	17,500	500
RTU-A4	17,000	17,300	300
Jenbacher Engine	0	41,350	41,350
Chiller/Heater	0	24,700	24,700
Cooling Tower	0	7,500	7,500
TOTALS	**66,000**	**144,150**	**78,150**

- Affected bays redesigned to withstand new loads
- In addition to gravity loads, engine vibration was also considered
- Composite wide flange system, along with a housekeeping pad and inertia base damper the engine vibration

Structural Impact

Structural Change Results



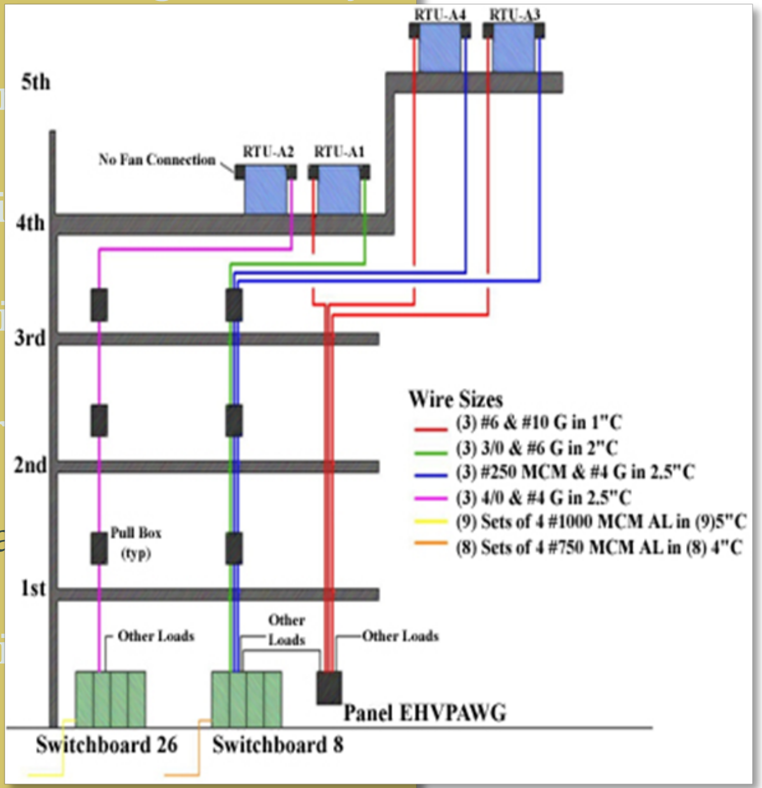
- Larger structural members needed to support newly introduced equipment
- Joists replaced by wide flanged members in areas where vibration is present
- A capital cost increase of $130,000

Electrical Impact

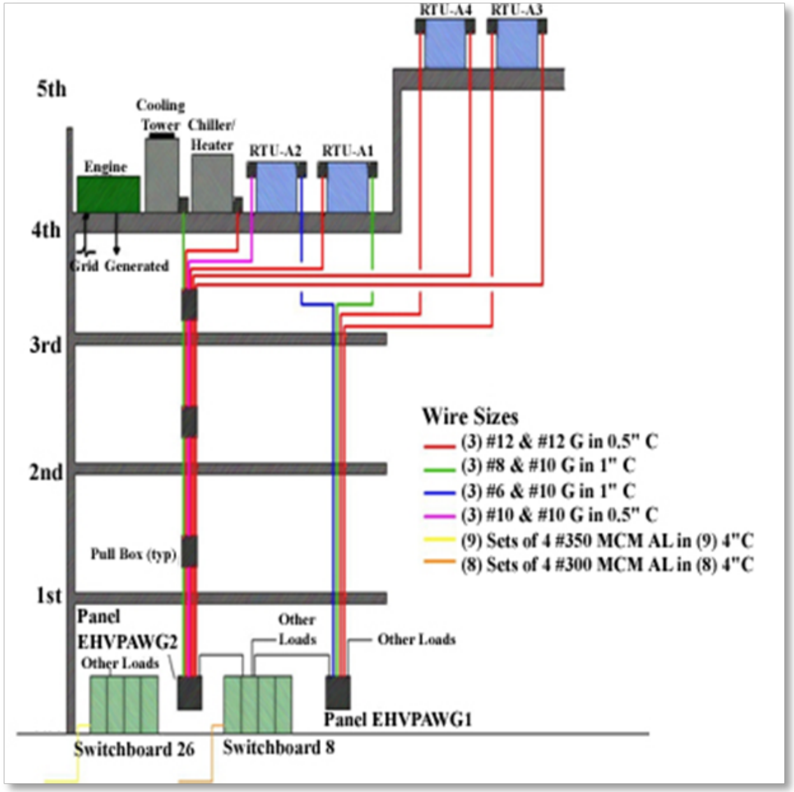
Presentation Contents

New Electrical Demand

- Less electrically driven equipment results in less electrical work
- Redesign reduces electrical demand by 300 to 400 kW depending on the time of year



Existing Riser Diagram



Redesign Riser Diagram

Electrical Impact







Electrical Change Results

- Less materials needed for conductors and conduits
- Two switchboards reduced in size
- All resulting in a price reduction

Overall saving from electrical changes results in nearly $80,000

Conclusions

Presentation Contents

Original Goals and Results

- Environmental
  - Highly reduces environmental impact
  - Achieved by using naturally occurring source of fuel in lieu of coal burning grid
- Public Relations
  - Avoids the highly publicized environmental impact lawsuit
  - Takes a negative situation and creates a positive story
  - The community no longer questions the need of an indoor ski resort
- Economic
  - Extra $7.5 million in initial cost could have reduced the $700 million from delays
  - Multiple year LFG contract prevents the impact of rising utility rates
  - Over 20 years the owner saves over $22 million
  - Landfill gas collection system creates more local job benefiting the community
- Health
  - Reduced impact of global warming
  - Reduction in emissions reduces local pollution, increasing air quality

Thus, a current liability has been converted into an asset for all!

Conclusions

Acknowledgements

Thank you to:

Thesis Advisor: James D. Freihaut, Ph.D.

Project Sponsor: Turner Construction Company

Sponsor Liaison: Steve Annesse

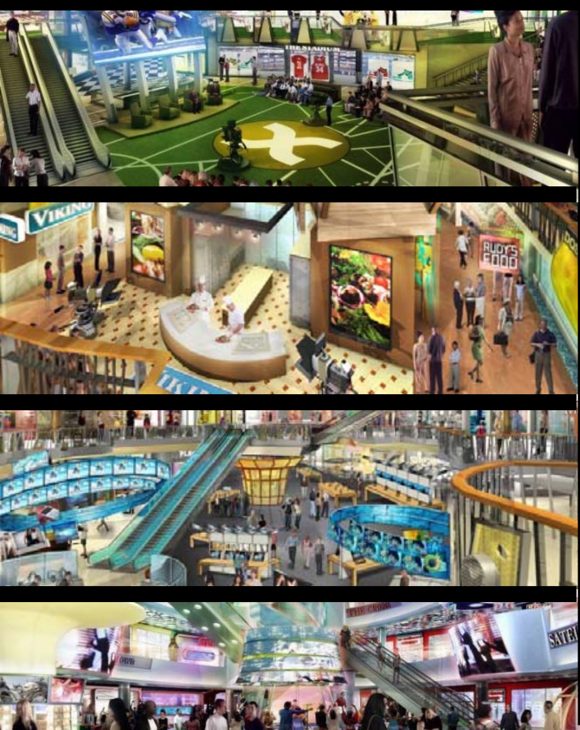
Structural Help: Steven Reichwein
Linda M. Hanagan, Ph.D., P.E.

The Penn State University Architectural Engineering Faculty

And my friends and family for all their support

Jason M. Sambolt
Mechanical Option

Questions?

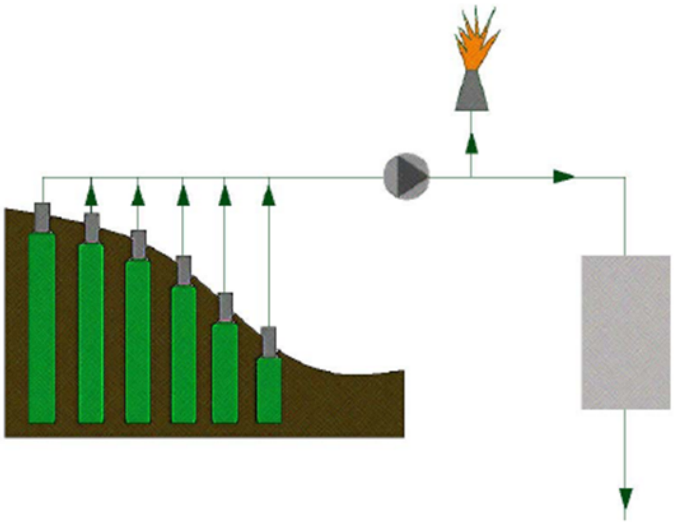


From Liability to Asset:

The Use of Renewable Energy and Cogeneration

Xanadu Meadowlands Sports Complex Building A
East Rutherford, New Jersey

GROWS Inc. Landfill



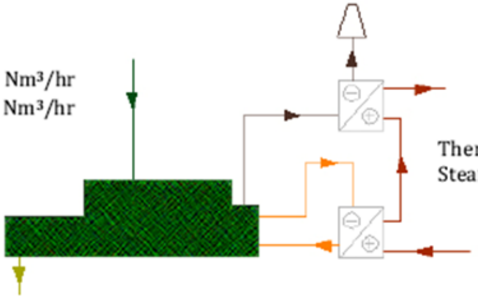
Landfill Gas Flowrate = 1,645 Nm³/h

Approximate Size: 4,053,804 ft²
Average Gas Production* = 0.344 scf/ ft²/day

Landfill Gas = (4,053,804 ft²) x (0.344 scf/ ft²/day) / (24 hours) = 58,104 scf/hr
Landfill Gas Produced = (58,104 scf/hr) = **1,645 Nm³/h**

*Sources: Waste Management http://www.americanlandfill.com/facility/gas_to_energy.asp
http://www.mrwmd.org/landfill-gas-power.htm

Engine: Jenbacher JMS 620 GS- NL

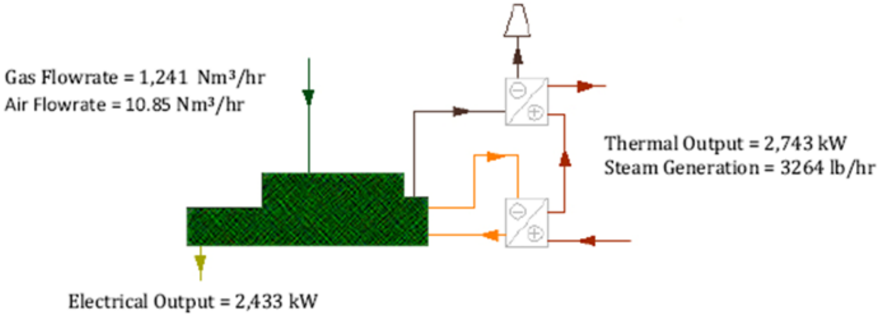


Natural Gas:

- Natural Gas Volume Flowrate = 745 Nm³/hr
- Fuel Lower Heating Value = 9.5 kWh/Nm³
- Electrical Efficiency = 43.0%
- Thermal Efficiency = 42.7%
- Total Efficiency = 85.7%
- Exhaust Gas to HX = 41.6%
- Exhaust Gas Volume Flowrate = 13.66 Nm³/hr
- Full Load Exhaust Gas Temperature = 425°C
- Steam Generated Pressure = 125 psig
- Steam Total Heat = 1,193 (Btu/lb)
- Combustion Air Volume Flowrate = 13.01 Nm³/hr
- Hot Water Volume Flowrate = 129.7 m³/hr

Max Electrical Output = (745 Nm³/hr) x (9.5 kWh/Nm³) x (0.43) = **3,043 kW**
Max Thermal Output = (745 Nm³/hr) x (9.5 kWh/Nm³) x (0.427) = **3,022 kW**
Steam Generation = (3,002 kW) x (3,412 Btu/hr/kW) / (1193 Btu/lb) x (0.416)
= **3572 lb/hr**

Engine: Jenbacher JMS 620 GS- BL



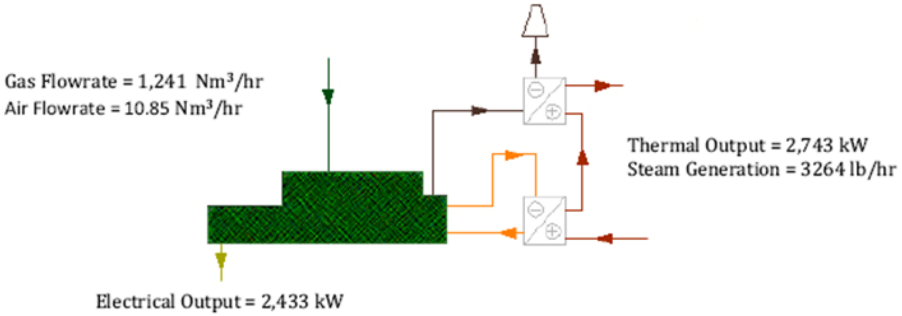
Landfill Gas:

Landfill Gas Volume Flowrate = 1,241 Nm^3/hr
Fuel Lower Heating Value = 5 kWh/Nm^3
Electrical Efficiency = 39.2%
Thermal Efficiency = 44.2%
Total Efficiency = 83.4%
Exhaust Gas to HX = 41.6%
Exhaust Gas Volume Flowrate = 11.78 Nm^3/hr
Maximum Demand Exhaust Gas Temperature = 467°C
Steam Generated Pressure = 125 psig
Steam Total Heat = 1,193 Btu/lb
Combustion Air Volume Flowrate = 10.85 Nm^3/hr
Hot Water Volume Flowrate = 78.5 m^3/hr

Summer

Max Electrical Output = (1,241 Nm^3/h) x (5 kWh/Nm^3) x (0.392) = **2,433 kW**
Max Thermal Output = (1,241 Nm^3/h) x (5 kWh/Nm^3) x (0.442) = **2,743 kW**
Amount of Flared Gas = (1,645 Nm^3/h) – (1,241 Nm^3/h) = **404 Nm^3/hr**
Max Steam Generation = (2,743 kW) x (3,412 Btu/h/kW) / (1193 Btu/lb) x (0.416)
= **3264 lb/hr**
Min Fuel Input = (2,407 kW) / (5 kWh/Nm^3) / (0.392) = **1,228 Nm^3/hr**
Min Thermal Output = (1,228 Nm^3/h) x (5 kWh/Nm^3) x (0.442) = **2,714 kW**
Min Steam Generation = (2,714 kW) x (3,412 Btu/h/kW) / (1193 Btu/lb) x (0.416)
= **3,229 lb/hr**

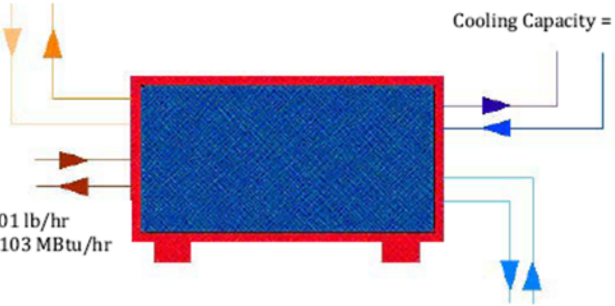
Engine: Jenbacher JMS 620 GS- BL (cont.)



Winter

Max Fuel Input = (1,855 kW) / (5 kWh/Nm^3) / (0.392) = **946 Nm^3/hr**
Max Thermal Output = (946 Nm^3/h) x (5 kWh/Nm^3) x (0.442) = **2,092kW**
Max Steam Generation = (2,092 kW) x (3,412 Btu/h/kW) / (1193 Btu/lb) x (0.416)
= **2489 lb/hr**
Min Fuel Input = (1,832 kW) / (5 kWh/Nm^3) / (0.392) = **935 Nm^3/hr**
Min Thermal Output = (935 Nm^3/h) x (5 kWh/Nm^3) x (0.442) = **2,066 kW**
Min Steam Generation = (2,066 kW) x (3,412 Btu/h/kW) / (1193 Btu/lb) x (0.416)
= **2458 lb/hr**

Absorption Chiller/Heater: Carrier 16NK



Double-Effect and Steam Fired
Cooling Capacity = 1034 kW = 294 Tons = 3,528,000 Btu/hr
Chilled Water Volume Flowrate = 44.4 L/s = 11.7 gal/s
Cooled Water Temperature = 45°F
Cooled Water Volume Flowrate = 74.2 L/s = 1,176 gpm
Steam Consumption = 1180 kg/h = 2601 lb/hr

Energy Input = (2,601 lb/hr) x (1,193 Btu/lb) = **3,103 MBtu/hr**
Energy Output = **3,528 MBtu/hr**
COP = (3,528 MBtu/hr) / (3,103 MBtu/hr) = **1.14**

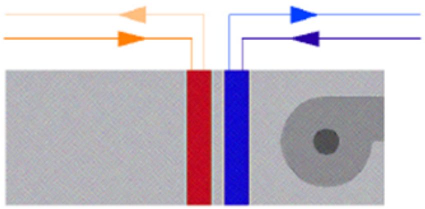
Cooling
Full Load Demand
Engine Steam Produced = **3,264 lb/hr**
Chiller Steam Consumption = **2,601 lb/hr**
Excess Steam = (3264 lb/hr) – (2601 lb/hr) = **663 lb/hr**
Partial Load Demand
Engine Steam Produced = **3,229 lb/hr**
Chiller Steam Consumption = **2601 lb/hr**
Peak Steam Consumption= **2,601 lb/hr**
Excess Steam = (3264 lb/hr) – (2601 lb/hr) = **628 lb/hr**

(Even at the minimum demand there is still enough steam to meet the maximum cooling load, therefore a standby centrifugal chiller is not needed.)

Heating
Minimum Load Demand
Engine Steam Produced = **2458 lb/hr**
Steam Capacity = (2458 lb/hr) x (1,193 Btu/lb) = **2,932 MBtu/hr**
Peak Heating Demand = **1,239 MBtu/hr**
Excess Steam Capacity = (2,932 MBtu/hr) – (1,239 MBtu/hr) = **1693 MBtu/hr**

(Even at the minimum electrical demand there is still enough steam to meet the maximum heating load, therefore a standby gas-fired boiler is not needed.)

Rooftop Unit A1: TRANE Rooftop Unit



Peak Cooling = 77 tons
Peak Heating = 337 MBtu/hr
Peak Supply = 29,477 cfm
Peak Return = 24,761 cfm
Peak Outside Air = 16%
Total Static Pressure = 2.0 inches
Return Static Pressure = 0.8 inches

Step 1: Casing Size
Peak Heating = 337 MBtu/hr from Table GD-1 **Casing 2** is selected

Step 2: Supply and Exhaust Fan
Peak Supply = 29,477 cfm and External Static Pressure = 2.0 inches
a **supply fan at 25 bhp and 1043 rpm** is selected
Peak Return = 24,761 cfm and Return Static Pressure = 0.8 inches
an **exhaust fan at 10 bhp and 750 rpm** is selected

Step 3: Hot Water Heating System
Supply Fan Heat = (25 bhp x 2.8) = **70 Mbtu/hr**
Supply Fan Temperature Rise = 70,000 Btu / (1.085 x 29,477 cfm) = **2.19°F**
Mixed Air Temperature = 70°F + (0.16)(0°F - 70°F) = **58.8°F**
Total Winter Heating Load = 337 MBtu/hr - 20.3 Mbtu/hr = **316.7 Mbtu/hr**
Steam Needed = (316,700 Btu/hr) / (1,193 Btu/lb) = **265.5 lb/hr**
Steam Remaining = (2458 lb/hr) – (265.5 lb/hr) = **2192.5 lb/hr**

Step 4: Chilled Water Cooling System
Peak Cooling = 77 tons = **924,000 Btu/hr**
Water Leaving Temperature = [(924,000 Btu/hr) / (500) / (294 gpm)] + 45°F = **51°F**
ΔT_L = 90°F - 51°F = 39°F
ΔT_S = 55°F - 45°F = 10°F
LMTD = **21.3°F** (From LMTD Table)
Capacity = 232,000 Btu/hr/row (Coil selection chart)
Rows = (924,000 Btu/hr) / (232,000 Btu/hr/row) = 3.98 rows = **4 Rows**