Image © <www.neomed.edu>

# NEOMED Research and Graduate Education Building + Comparative Medical Unit Expansion

## the Northeast Ohio Medical University Campus
## Rootstown, Ohio

Sam Bridwell, BAE  Mechanical Option  Advisor: Dr. Freihaut


Image © <www.crystaldiagnostics.com>

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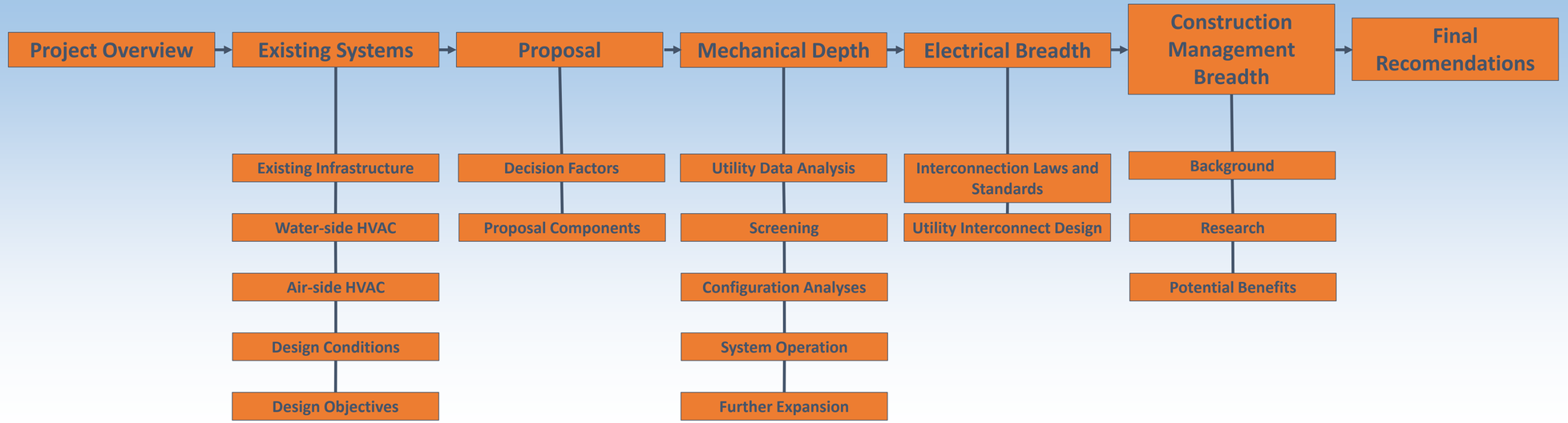

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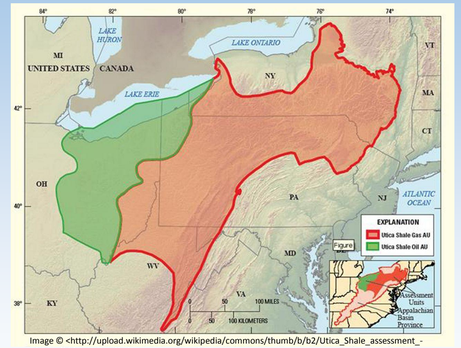
# Project Location

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**Utica Shale Region**

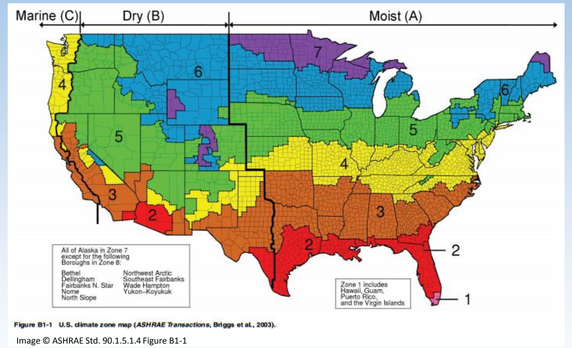


**Figure B1-1 U.S. climate zone map (*ASHRAE Transactions*, Briggs et al., 2003).**

Image © ASHRAE Std. 90.1.5.1.4 Figure B1-1

**5A Cool and Moist**

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# Campus Map

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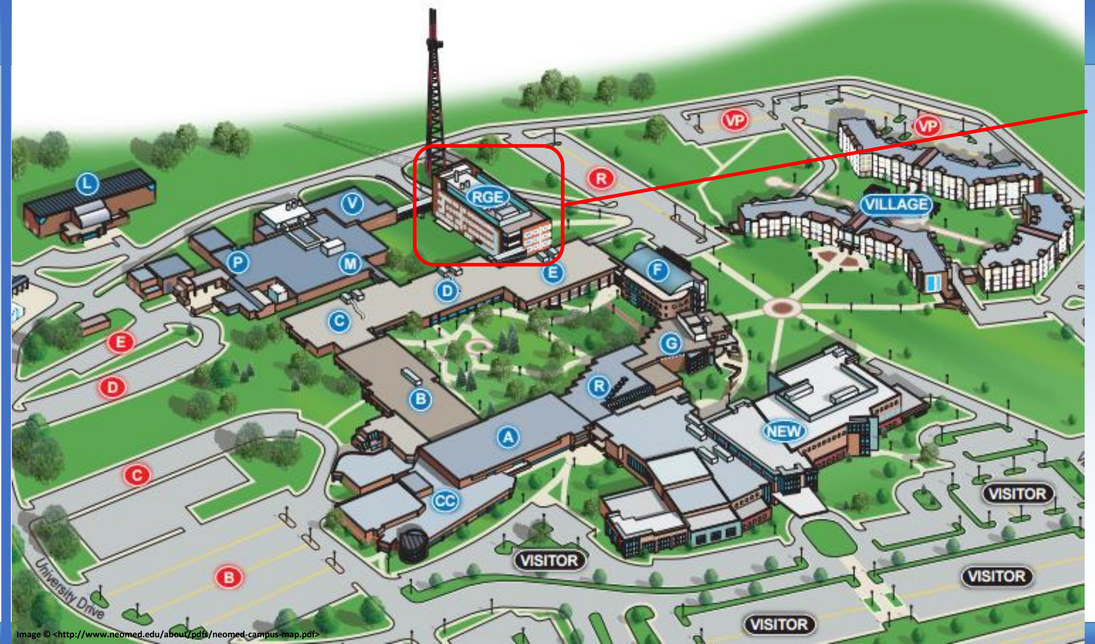


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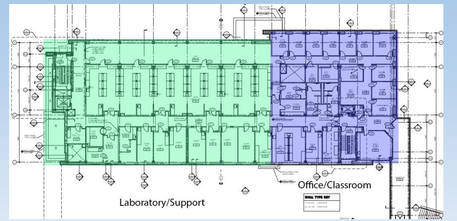
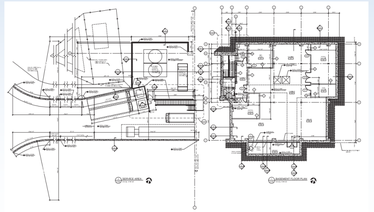
# Phase 1

Research and Graduate Education Building

Image © <http://www.ruhlin.com/highered-neomedrgecmu>



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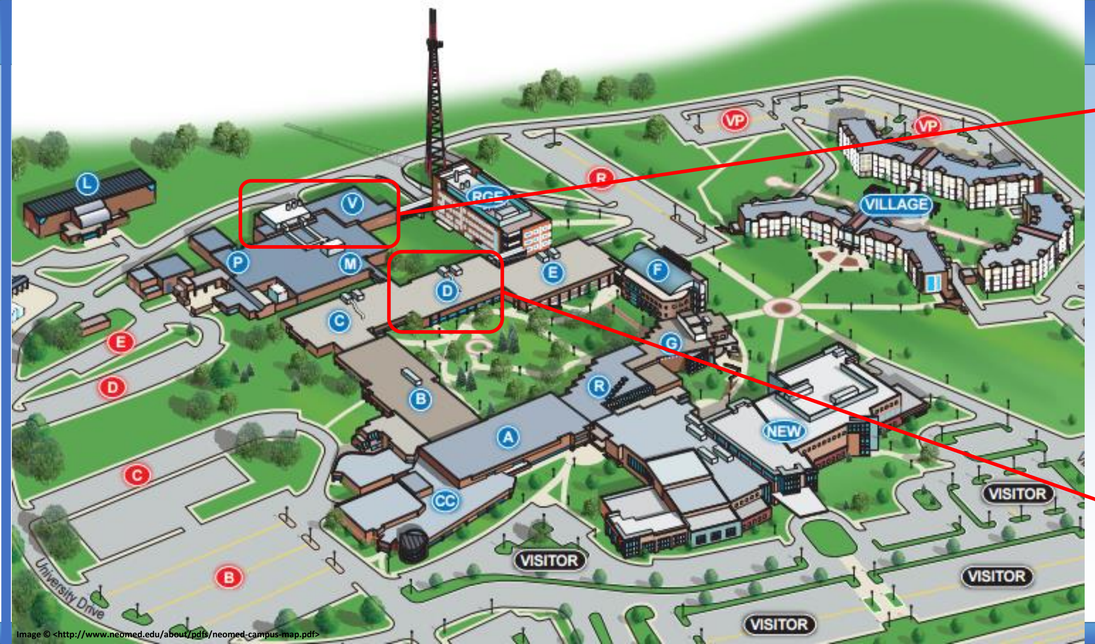


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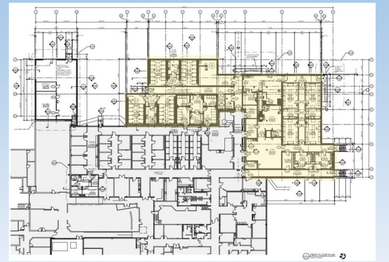
# Phase 1

Comparative Medical Unit Expansion



REDI-Zone

Image © Scheeser Buckley Mayfield LLC

Image © Scheeser Buckley Mayfield LLC

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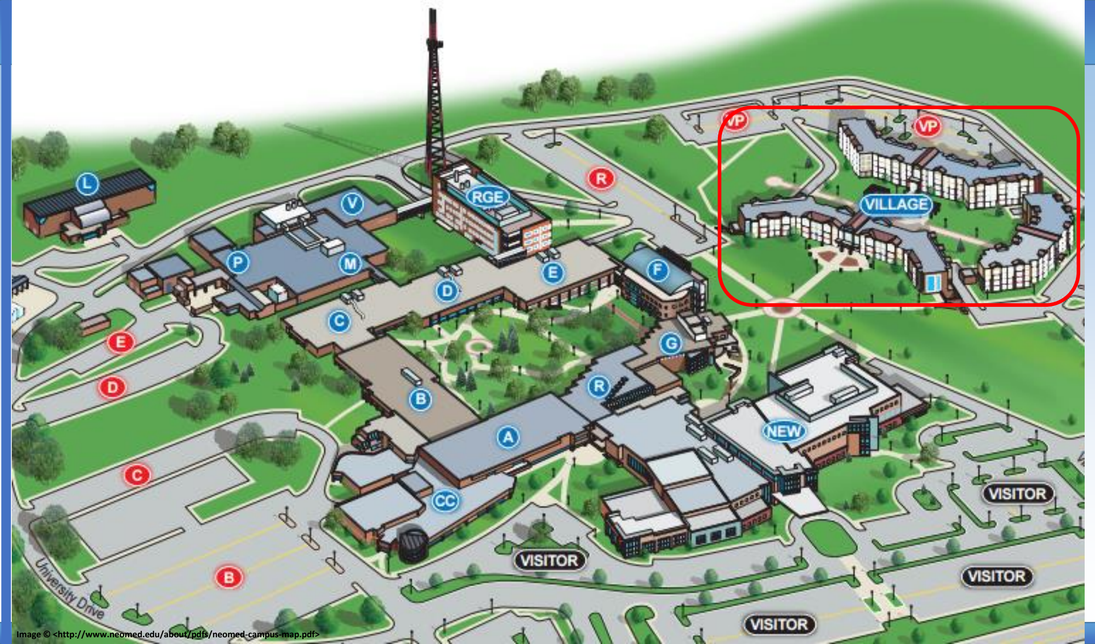


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# The Village

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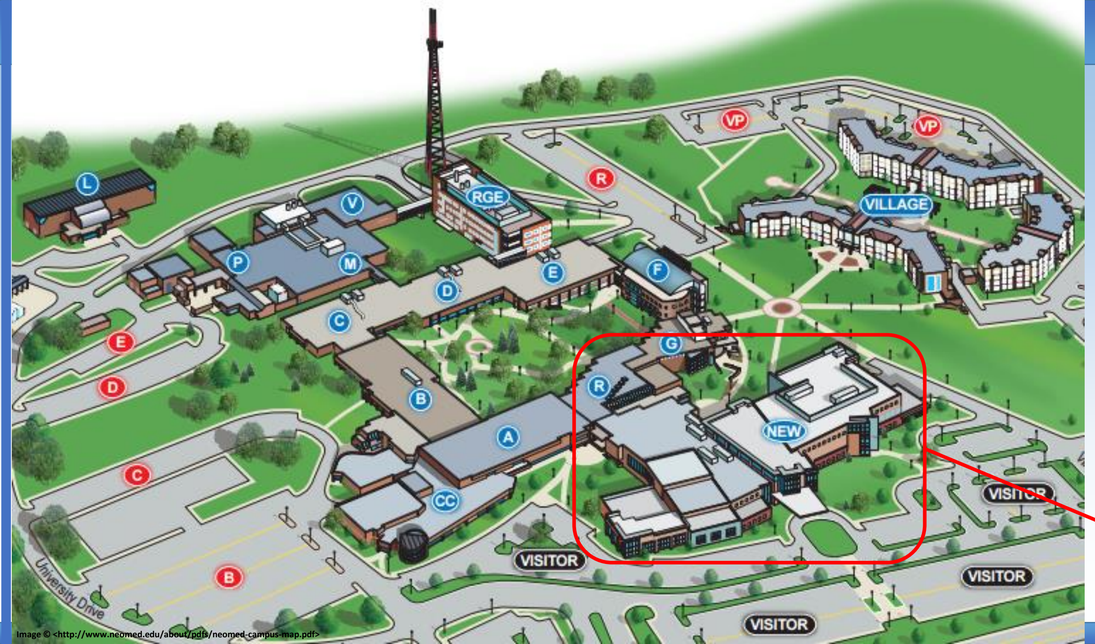


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# Phase 2

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NEOMED Education and Wellness Center

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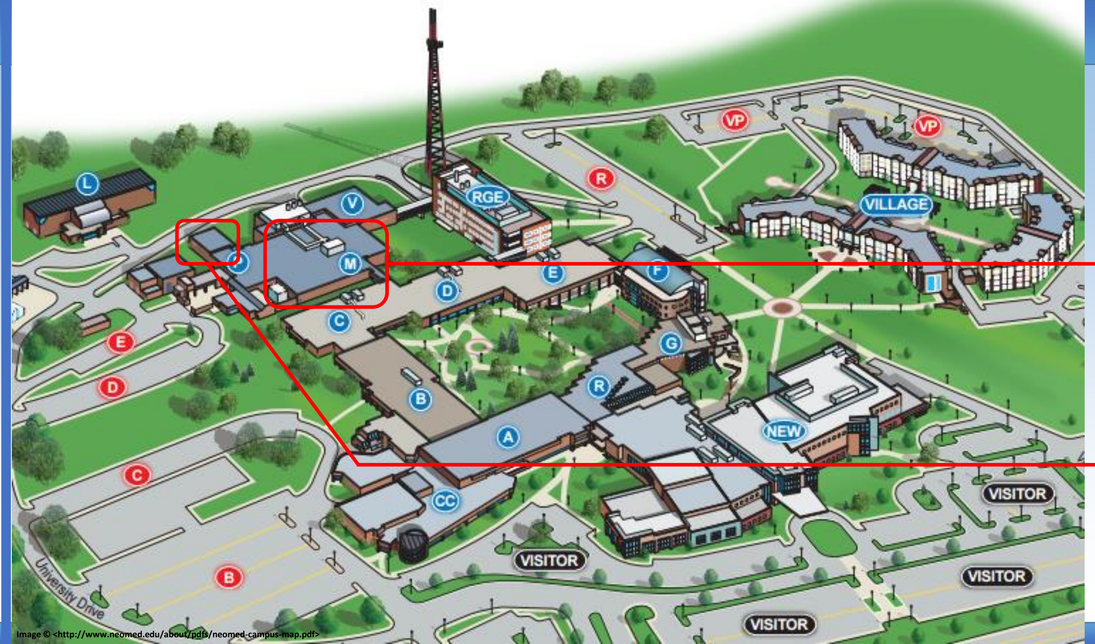


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# Existing Infrastructure

Main HW/CW Plant

High-Pressure Steam Plant

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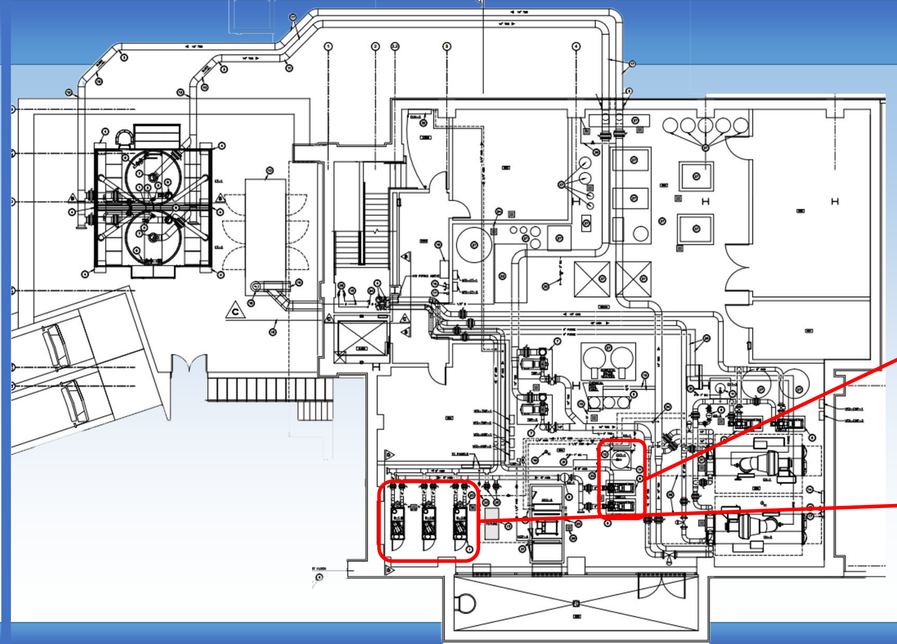

# RGE Standalone Utilities

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Image © Scheeser Buckley Mayfield LLC

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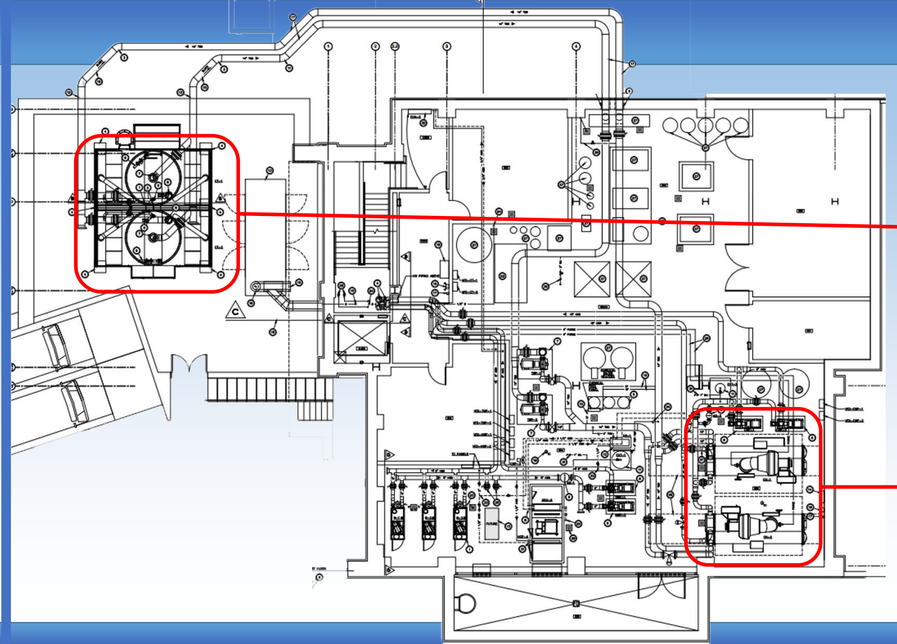

# RGE Standalone Utilities



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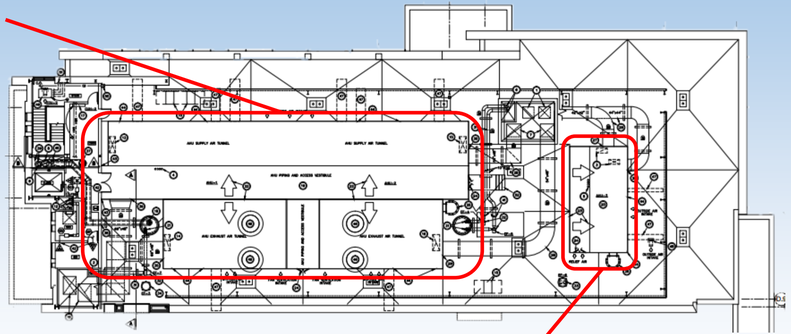
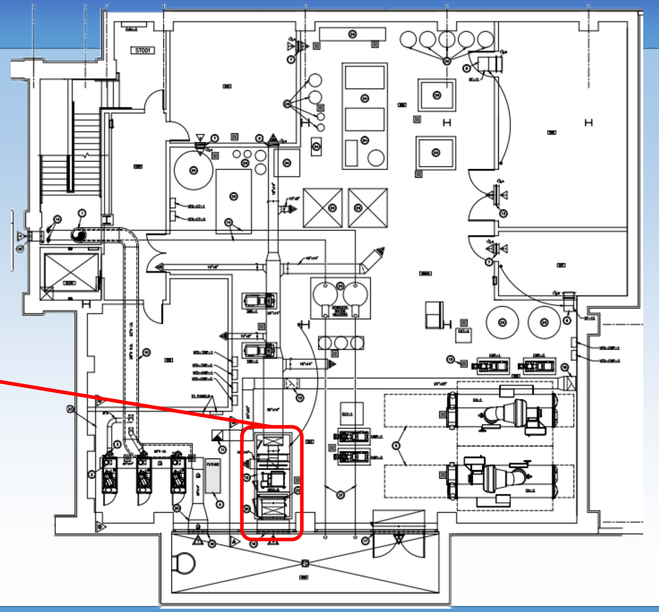
# Custom RTU's

AHU-1 and AHU-2
50,000 CFM
100% OA



AHU-3
28,000 CFM

AHU-4
8,400 CFM



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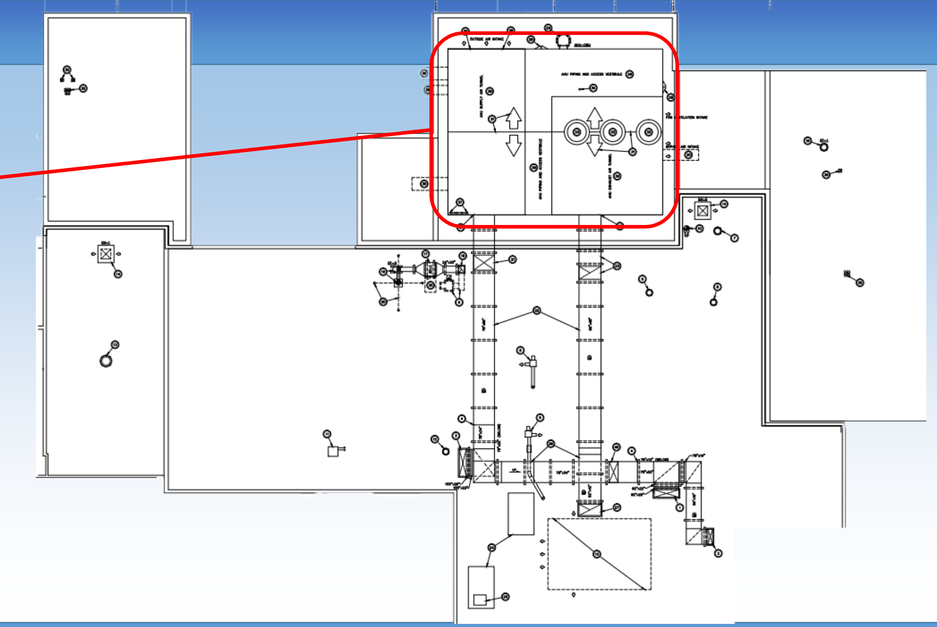
# Custom RTU's



AHU-5
85,000 CFM
100% OA



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# Design Conditions

1) Filtration Levels

   (a) Supply air tunnel to have MERV-9 pre-filter and MERV-14 after filter within AHU (serving new and existing Vivarium).

   (b) Room side replaceable "Filter Grilles" to be utilized for holding room exhaust.

   (c) Heat pipe energy recovery (within exhaust) to have MERV-9 pre-filters.

2) Chilled Water Design: 42°F EWT, 58°F LWT

3) Hot Water Design: 160°F EWT, 120° LWT

4) Steam System Design: 60 psig – process (Autoclaves + Cagewasher)
   15 psig – (Humidification) reduced by new PRV

Image © BR+A Consulting Engineers

| | Winter °F | Summer °F (±2°F) |
|---|---|---|
| Exterior Design Temp. | 0 | 89°db /73°wb |
| Interior Design Temp. | | |
| Laboratories / support spaces | 72 | 72 |
| Mechanical/Electrical Rooms | 65 | Vent Only |
| Animal Holding Rooms | 68-85 | 68-85 (Selectable range) |
| Rabbits Holding Room | 65 | 65 |
| Supply Air Temperature (at discharge of chilled water coil) | 48°F db | 48°F db /47.5° wb Vivarium |
| Humidity | | |
| Lab / Support spaces | 35%±5 | 50% (±5%) |
| Vivarium | 30-40%±5 | 50% (±5%) |

Image © BR+A Consulting Engineers

a. The HVAC systems and equipment shall be designed in accordance with the following Ventilation / Pressurization / Cooling criteria:

1) Laboratories and support spaces
   Exhaust: 100% Exhaust.
   Air Circulation: As required by air conditioning load or equipment ventilation load. Min. 6 ACH/HR.
   Pressure: Negative in relation to corridors and office spaces
   Electrical Loads: 10 w/sf power, 2 w/sf lighting

2) Toilets/Janitors Closets
   Exhaust: 100% Exhaust
   Air Circulation: 10 ACH exhaust (min.), constant volume
   Pressure: Negative to adjacent spaces
   Electrical Loads: 1.5 w/sf lighting, convenience outlets

3) Animal Holding
   Exhaust: MERV-9
   Air Circulation: Minimum 15 ACH, constant volume
   Pressure: Negative to adjacent spaces
   Electrical Loads: 10 w/sf power, 1.5 w/sf lighting

4) Procedure Room
   Exhaust: 100% Exhaust
   Air Circulation: 15 ACH minimum, as required for equipment makeup ventilation Load, constant volume
   Pressure: Negative to adjacent spaces
   Electrical Loads: 15 w/sf power, 2 w/sf lighting

5) Operating Rooms
   Exhaust: 100% Exhaust
   Air Circulation: 15 ACH minimum, as required for cooling
   Pressure: Positive
   Electrical Load: 15 w/sf power; 2 w/sf lighting

6) Airlocks
   Exhaust: 100% Exhaust
   Air Circulation: 10 ACH minimum, constant volume
   Pressure: Negative to adjacent spaces
   Electrical Loads: 1.5 w/sf lighting

7) Corridors
   Exhaust: 100% Exhaust
   Air Circulation: Minimum 6 ACH or requirement for make-up due to labs being at negative pressure.
   Pressure: Positive to Laboratories
   Electrical Loads: 1.5 w/sf lighting

8) Environmental Rooms
   Exhaust: 100% Exhaust
   Air Circulation: 20 CFM ventilation only
   Pressure: Neutral

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# Design Objectives

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Image © <http://www.laborcosting.com>

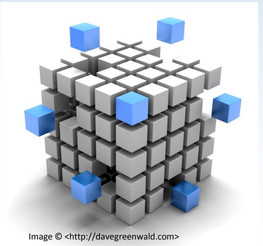
**Top-Notch Quality of Facility**

**24/7 Availability for Staff and Researchers**

**Independence and Reliability of Building Systems**

**Flexibility for Future Changes and Campus Expansion**

Image © <http://www.transactbookkeeping.co.uk/images/reliability.jpg>



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# Considerations Made

**High Air Turnover, Need for Energy Recovery**

**Multi-Phase, Multiple Bids**

**Complex Controls and Metering**

**Distance to Existing Utilities**

**Strict Technical Requirements**

**Environmental Impact**

**Ease of Maintenance**

**Goal of Long-Term Growth and Development**

**Strict Project Delivery Timeline**

**Cost Impact**

**Efficiency**

**Atypical Building Systems**

**Built to Benefit not only Students and Researchers but Entire Regional Community**

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# Proposed Alternatives

## Breadth 1: Power Interconnect & Black Start Capability

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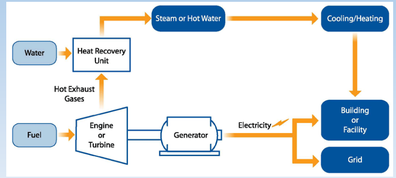
## Depth: Cogeneration Plant Implementation



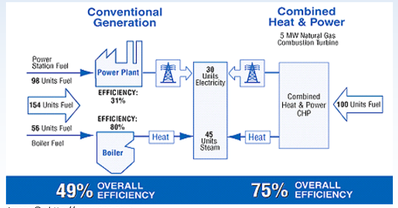
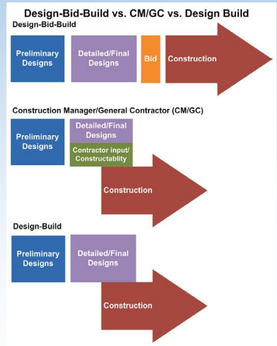




Image © <http://www.epa.gov>

## Breadth 2: Alternate Project Delivery System

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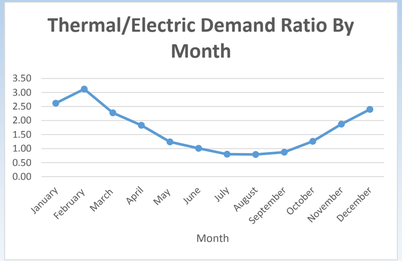
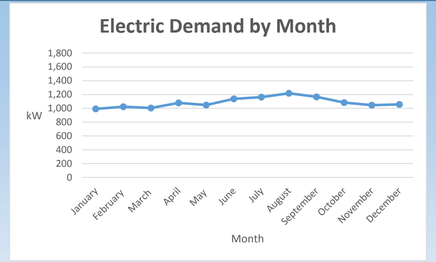
# Campus Utility Data

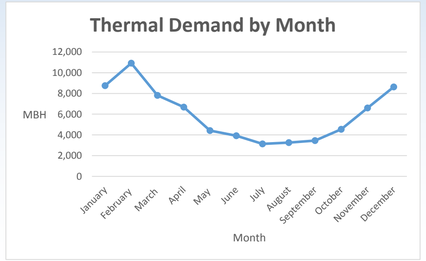
| | | Year |
|---|---|---|
| **Month** | Kilowatt Hrs | 823,121 |
| | Dollars | $62,575.46 |
| | **$/kwh** | **$0.076** |
| | Temperature | 74° |

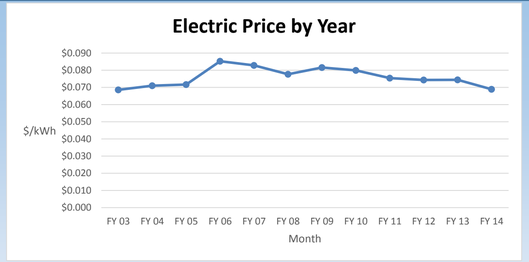
| | | Year |
|---|---|---|
| **Month** | MCF's | 2,139.01 |
| | Dollars | $16,962.35 |
| | **$/MMBTU** | **$7.93** |
| | Temperature | 74° |

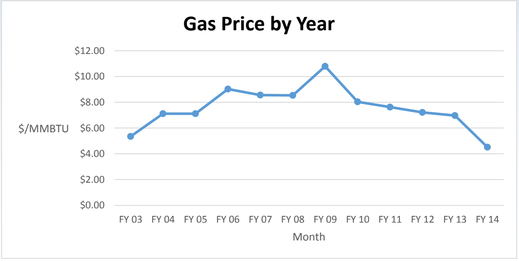
| | | |
|---|---|---|
| **Yearly Average** | $/kwh | $0.077 |
| | $/MMBTU | $7.85 |
| | **Spark Gap** | **$14.60** |
| | kW | 1084 |
| | MBH | 6010 |
| | **ΔD** | **1.63** |
| | Temperature | |



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# System Selection

**Site Data Collection**

| | | |
|---|---|---|
| 1. How many hours per year does the facility operate? (hours) Or, ask about operating schedule - day/week, hours/day | 8,760 | |
| 2. What is your average power demand during operation? (kW), or | 1,084 | |
| 3. How much electricity do you use in a year, kWh? | 9,369,859 | |
| 4. What is your facility's primary thermal load (i.e., DHW, steam/HW space heating, process steam, cooling, etc.) | Space Heating | |
| 5. What is your average thermal demand? (MMBtu/hr), or | 6.01 | |
| 6. How much fuel (gas/oil/etc) do you use in a year? (MMBtu/yr, Therms/yr, etc.) | 51,922 | |
| 7. What is your current fuel price? ($/MMBtu) | $7.850 | |
| 8. How much do you pay for fuel annually? (Dollars/yr) | $405,770 | |
| 9. What are the CHP Fuel Costs? ($/MMBtu) | $7.850 | |
| 10. What is your average electricity price? ($/kWh) | $0.077 | |
| 11. How much do you pay for electricity annually? (Dollars/yr) | $712,509 | |
| 12. What is the efficiency of your existing boiler(s)/thermal equipment? (decimal) | 0.90 | RGE HW Boiler |
| 13. What is the efficiency of your existing chillers? (kWh/ton) | 0.60 | RGE Chiller |

**CHP System**

| | | | |
|---|---|---|---|
| Net CHP Power, kW | 1,084 | CHP System Specs | C |
| CHP Electric Efficiency, % (HHV) | 36.8% | CHP system specs | C |
| CHP Thermal Output, Btu/kWh | 3,854 | CHP system specs | C |
| CHP Thermal Output, MMBtu/hr | 4.2 | CHP system specs | C |
| CHP Power to Heat Ratio | 0.89 | Calculated based on CHP power output and thermal output | |
| CHP Availability, % | 98% | 90 to 98% | |
| Incremental O&M Costs, $/kWh | $0.019 | CHP system specs | C |
| Thermal Utilization, % | 90% | Amount of available thermal captured and used - typically 80 to 100% | |
| Total Installed Costs, $/kW | $2,335 | CHP system specs | C |

| | Based on Recip Engines | | | | Based on Gas Turbines | | | |
|---|---|---|---|---|---|---|---|---|
| Thermal Output, MMBtu/hr | 0.34 | 2.64 | 3.85 | 10.67 | 24.47 | 52.62 | 76.42 | 141.33 |
| Net Capacity, kW | 50 | 600 | 1,000 | 3,300 | 5,000 | 10,000 | 20,000 | 45,000 |
| System | A | B | C | D | E | F | G | H |
| Heat Rate, Btu/kWh | 12,637 | 9,896 | 9,264 | 8,454 | 11,807 | 12,482 | 10,265 | 9,488 |
| Net Electrical Efficiency, % | 27.0% | 34.5% | 36.8% | 40.4% | 28.9% | 27.3% | 33.2% | 36.0% |
| Thermal Output, Btu/kWh | 6,700 | 4,392 | 3,854 | 3,233 | 4,893 | 5,262 | 3,821 | 3,141 |
| Thermal Output, MMBtu/hr | 0.34 | 2.64 | 3.85 | 10.67 | 24.47 | 52.62 | 76.42 | 141.33 |
| Thermal Output for Cooling (single effect) | 80% | 85% | 85% | 85% | 100% | 100% | 100% | 100% |
| Thermal Output for Cooling (double effect) | 50% | 50% | 50% | 50% | 90% | 90% | 90% | 90% |
| Total Efficiency, % | 80% | | 78% | 79% | 70% | 69% | 70% | 69% |
| Incremental O&M, $/kWh | $0.0240 | $0.0210 | $0.0190 | $0.0126 | $0.0123 | $0.0120 | $0.0093 | $0.0092 |
| Total Installed Costs, $/kW | $2,900 | $2,737 | $2,335 | $1,917 | $2,080 | $1,976 | $1,518 | $1,248 |

## GE Jenbacher Reciprocating Engine

Image © <http://site.ge-energy.com/prod_serv/products/recip_engines/en/type3.htm>

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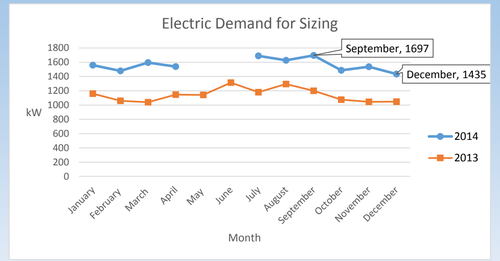
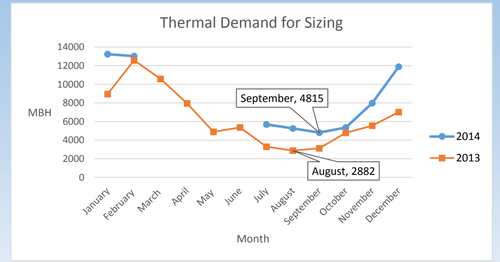
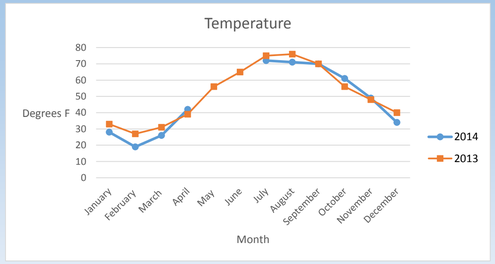
# System Sizing

| | | FY 14 |
|---|---|---|
| **Yearly Average** | $/kwh | $0.069 |
| | $/MMBTU | $4.51 |
| | **Spark Gap** | **$15.69** |
| | kW | 1565 |
| | MBH | 8418 |
| | **ΔD** | **1.58** |
| | Temperature | 0 |




| | | Cooling Months | | | | | |
|---|---|---|---|---|---|---|---|
| | | **June** | **July** | **August** | **September** | | |
| 2014 | total kW | | 1,689 | 1,627 | 1,697 | avg. (non-cooling) kW | 1,435 |
| | cooling power (kW) | | 254 | 193 | 262 | avg. (cooling) kW | 236 |
| | cooling load (MBH) | | 5087 | 3858 | 5240 | Avg. Cooling MBH | 4,728 |
| | cooling load (Ton) | | 424 | 322 | 437 | **Avg. Cooling Tons** | **394** |

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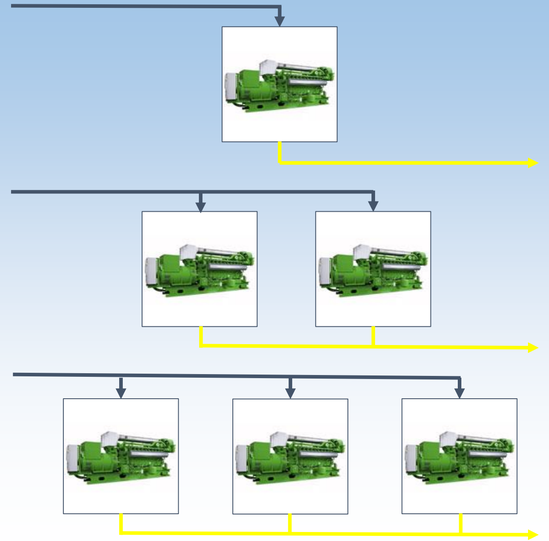
# Configurations



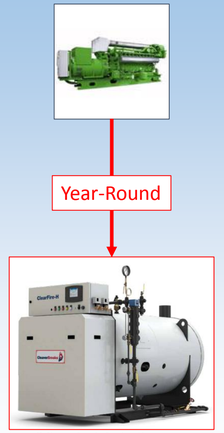
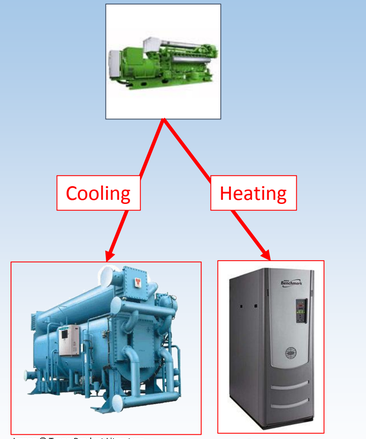



Image © Cleaver Brooks Product Literature

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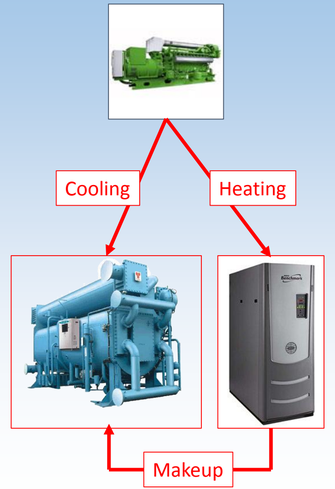

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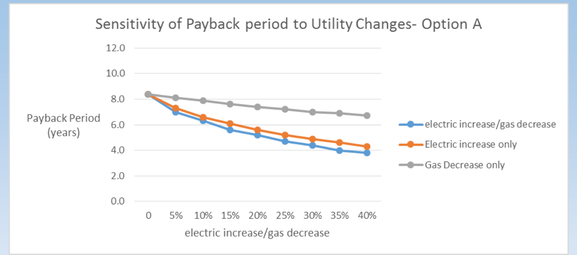
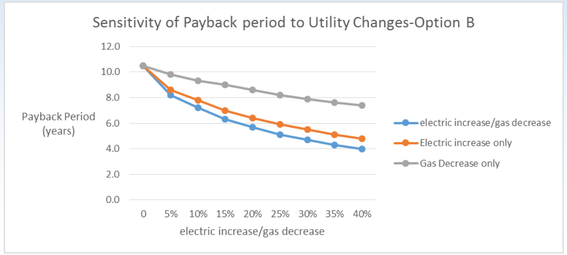
# Configuration Analysis

## Plant Configuration Results

| | | | Emissions | |
|---|---|---|---|---|
| Configuration | Equipment Setup | Payback Period | Vehicles | Houses |
| A | 1 GE Jenbacher J420 with process steam load | 8.4 | 2,201 | 1,439 |
| B | 2 GE Jenbacher J316 with process steam load | 10.5 | 2,630 | 1,720 |
| C | 3 GE Jenbacher J312 with process steam load | 14.4 | 2,945 | 1,926 |
| D | 1 GE Jenbacher J420 with trigeneration, absorption cooling sized to thermal output | 11.1 | 2,076 | 1,358 |
| E | 2 GE Jenbacher J316 with trigeneration, absorption cooling sized to thermal output | 11.4 | 2,461 | 1,610 |
| F | 3 GE Jenbacher J312 with trigeneration, absorption cooling sized to thermal output | 14.5 | 2,756 | 1,802 |
| G | 1 GE Jenbacher J420 with trigeneration, full load absorption cooling with boiler makeup | 11.4 | 2,076 | 1,358 |
| H | 2 GE Jenbacher J316 with trigeneration, full load absorption cooling with boiler makeup | 11.5 | 2,461 | 1,610 |
| I | 3 GE Jenbacher J312 with trigeneration, full load absorption cooling with boiler makeup | 14.5 | 2,756 | 1,802 |



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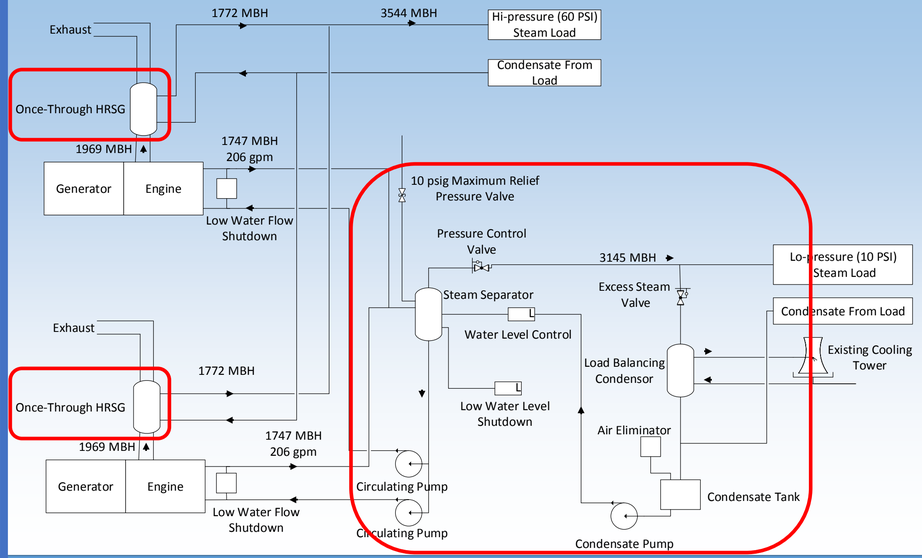
# Cogeneration System Schematic




## High-Temperature Water Steam System

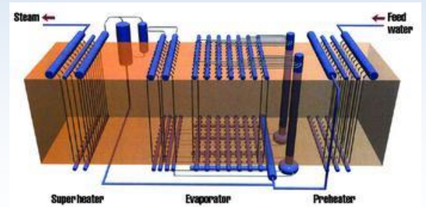



Image © <http://inproheat.com/sites/files/imagecache/product_nodeview/products/pic-onceThrough-zz_0.jpg>

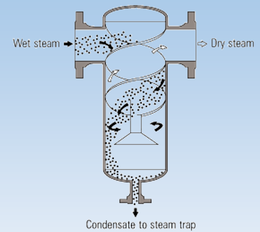



Image © <http://www.davegreenwald.com>

## Once-Trough Steam Generator

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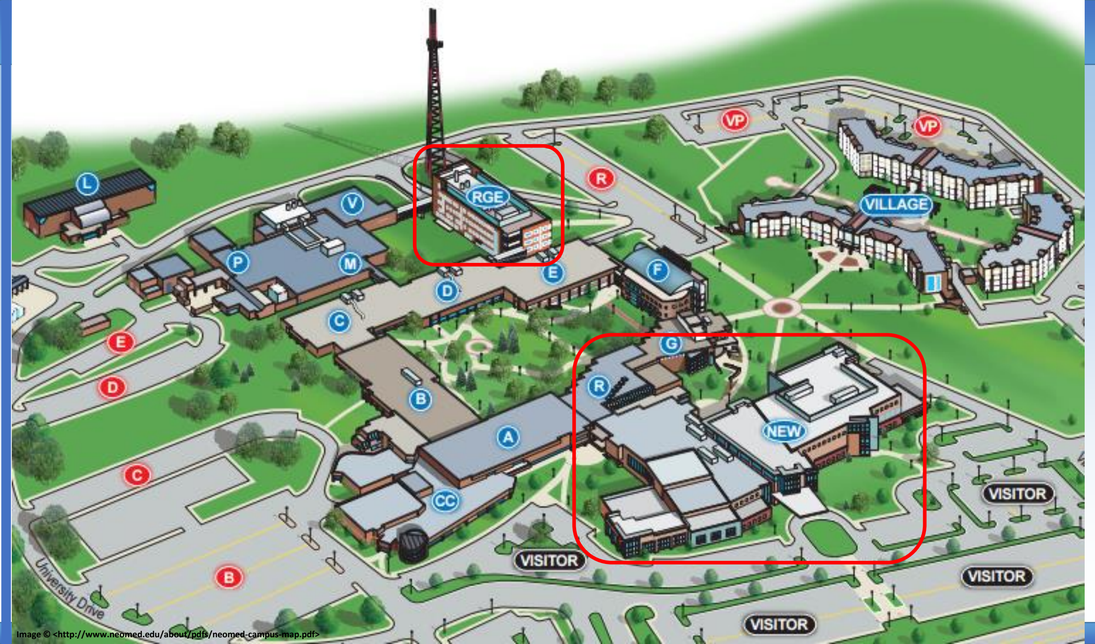


Image © <http://www.neomed.edu/about/pdfs/neomed-campus-map.pdf>

# Further Expansion

- **Generator Sizing Accommodates Expansion**
  - **Fit out of 4th Floor**
  - **AHU Humidifiers**

- **Locate Additional Plant Capacity in NEW Building**
  - **Lap Pool**
  - **Hydrotherapy Pool**

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# State Interconnect Laws and Standards

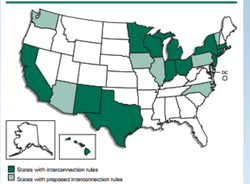
**Ohio has very "DG-Friendly" Policies**

**Disconnect Switch at discretion of Utility**

**No Generation System Size Limit for Interconnection**

**Net Metering mandated for all IOU's; No Generation System Size Limit**

**Figure 5.4.1: States with DG Interconnection Standards**




Notes:

- New Jersey also has interconnection standards for net metered renewable DG ≤ 2 MW.
- New Hampshire has interconnection standards for net metered renewable DG ≤ 25 kW.

| Maximum System Size for a State Interconnection Standard | | | |
|---|---|---|---|
| CA | None | NH | 25 kW |
| CT | 25 MW | NJ | 2 MW |
| DE | 1 MW | NM | 10 kW |
| HI | None | OH | None |
| MA | None | NY | 2 MW |
| MI | None | TX | 10 MW |
| MN | 10 MW | WI | 15 MW |
| NC* | 100 kW | | |

* System size is limited to 20 kW for residential customers.

***Source: Nevigant 2005.***



**Figure 5.4.2: States with Net Metering Rules**


| Net Metering System Size Limit (kW) (in some cases limits are different for residential and commercial as shown) | | | |
|---|---|---|---|
| AR | 25/100 | MN | 40 |
| AZ | 10 | MT | 50 |
| CA | 1,000 | ND | 100 |
| CO | Under development | NH | 25 |
| CT | 100 | NJ | 2,000 |
| DC | 100/25 | NM | 10 |
| DE | Varies | NV | 30 |
| FL | Varies | NY | 10/400 |
| GA | 10/100 | OH | No limit |
| HI | 50 | OK | 100 |
| IA | Varies | OR | 25 |
| ID | 25/100 | PA | Varies |
| IL | 40 | RI | 25 |
| IN | 10 | TX | 50 |
| KY | 15 | UT | 25 |
| LA | 25/100 | VA | 10/500 |
| MA | 60 | VT | 15/150 |
| MD | 80 | WA | 25 |
| ME | 100 | WI | 20 |
| MI | Varies | WY | 25 |

***Source: IREC 2005.***

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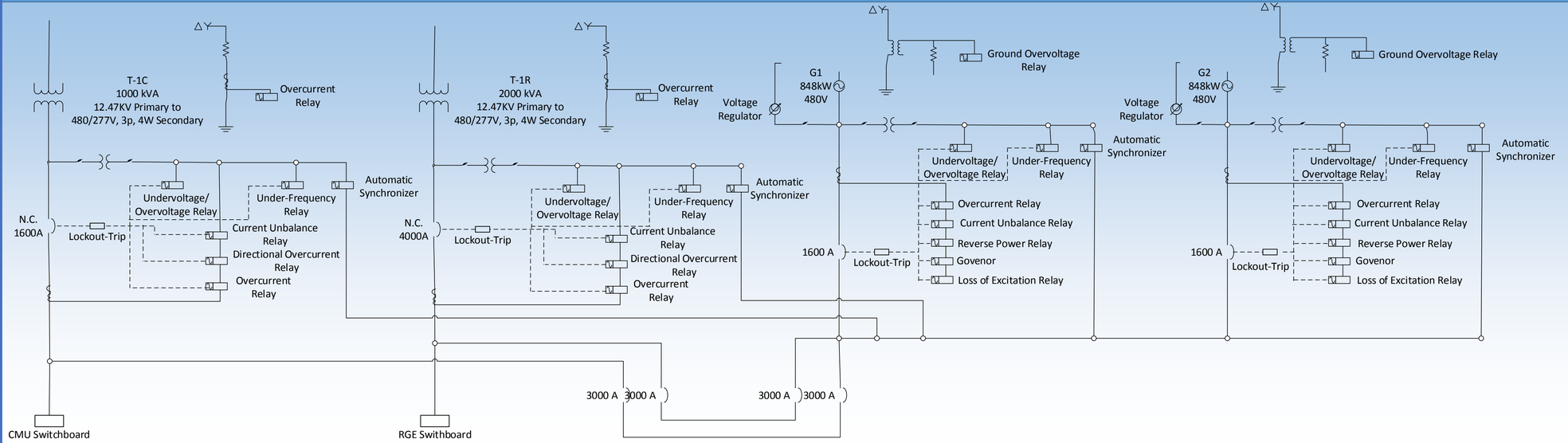
# Generation and Utility Parallel Operation Schematic



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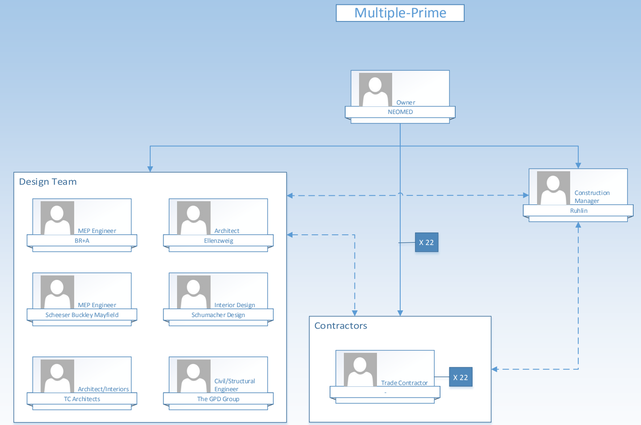
# Project Delivery Methods



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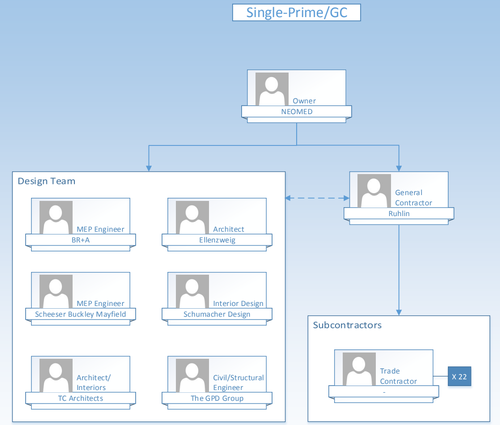
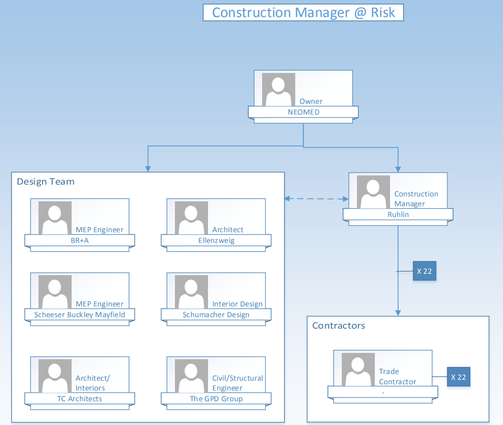
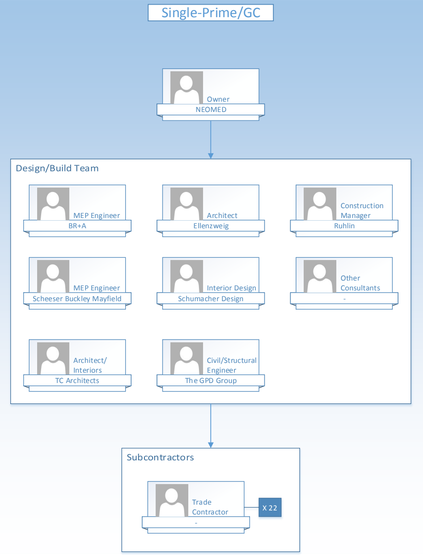
# Project Delivery Methods



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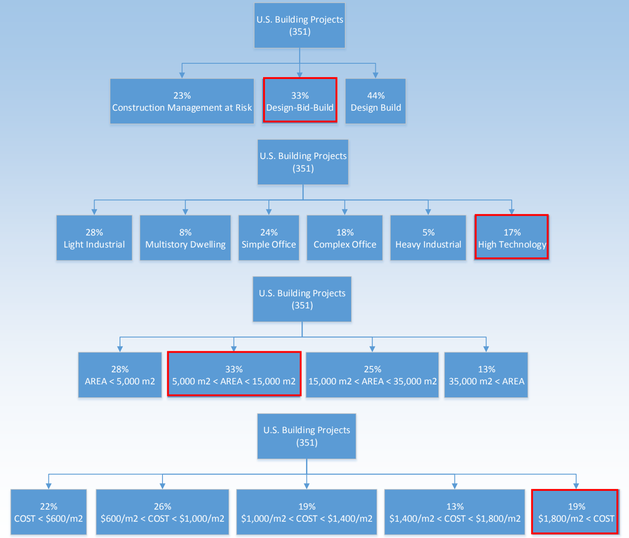
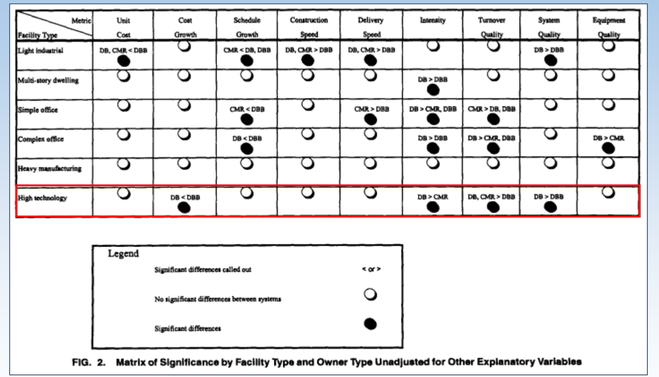
# Research Results



| Facility Type \ Metric | Unit Cost | Cost Growth | Schedule Growth | Construction Speed | Delivery Speed | Intensity | Turnover Quality | System Quality | Equipment Quality |
|---|---|---|---|---|---|---|---|---|---|
| Light Industrial | DB, CMR < DBB | ○ | CMR < DB, DBB | DB, CMR > DBB | DB, CMR > DBB | ○ | ○ | DB > DBB | ○ |
| Multi-story dwelling | ○ | ○ | ○ | ○ | ○ | DB > DBB | ○ | ○ | ○ |
| Simple office | ○ | ○ | CMR < DBB | ○ | CMR > DBB | DB > CMR, DBB | CMR > DB, DBB | ○ | ○ |
| Complex office | ○ | ○ | DB < DBB | ○ | ○ | DB > DBB | DB > CMR, DBB | ○ | DB > CMR |
| Heavy manufacturing | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| High technology | ○ | DB < DBB | ○ | ○ | ○ | DB > CMR | DB, CMR > DBB | DB > DBB | ○ |

Legend

| | |
|---|---|
| Significant differences called out | < or > |
| No significant differences between systems | ○ |
| Significant differences | ● |

FIG. 2. Matrix of Significance by Facility Type and Owner Type Unadjusted for Other Explanatory Variables

Image © Journal of Construction Engineering and Management Nov/Dec 1998

## Univariate Results

- 50% CMR and DB delivered on-time or early
- 50% DBB more than 4% late
- CMR,DB Quality > DBB Quality

## Multivariate Results

- DB < CMR DBB
- Delivery Method significant influence on construction speed, some influence on total delivery speed
- Delivery Method single biggest influence on schedule growth
- Project Delivery Method biggest influence on every metric overall, matched only by Facility Type

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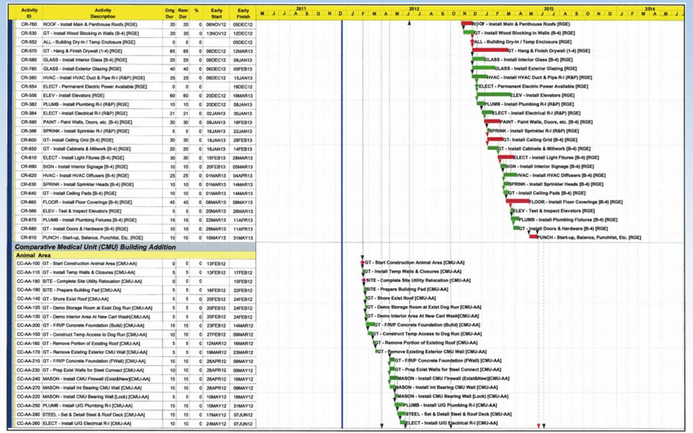
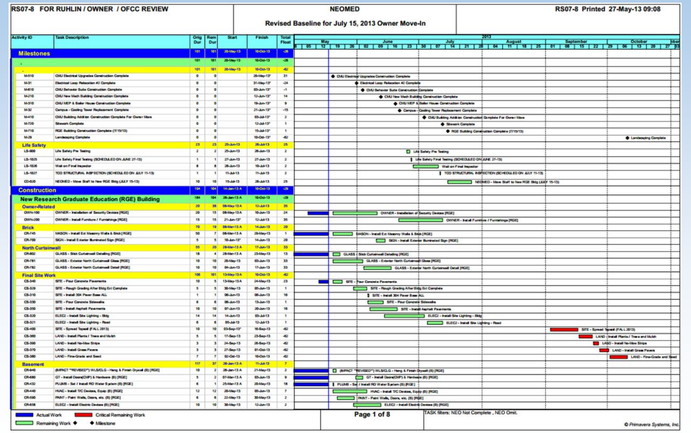
# Project Benefits

## Schedule Slippage

| | Bid Schedule | Actual Substantial Completion | Days Delayed |
|---|---|---|---|
| **CMU** | 5/13/2013 | 7/31/2013 | 79 |
| **RGE** | 5/31/2013 | 7/31/2013 | 61 |

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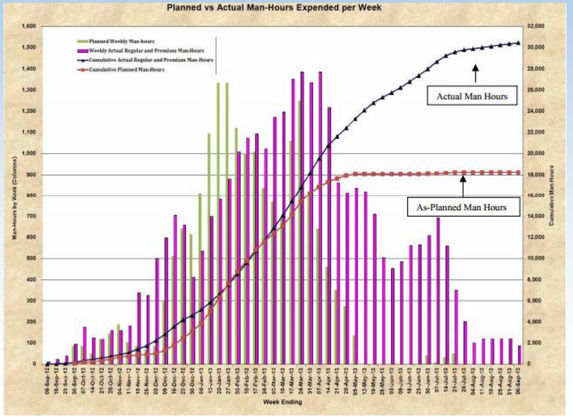
# Project Benefits


| | Actual Man-hours Expenditures | | | | | Base Contract Labor Dollars Earned | | | Man-hour per percent |
|---|---|---|---|---|---|---|---|---|---|
| Date | Cumulative Electrician Payroll hours | Less Field Supervision hours | Temporary Power & Clean up | Less Approved & Pending Change Orders | Net Cumulative Actual Man-hours | Period Earned Labor Dollars | Cumulative Earned Labor Dollars | Cumulative Percent Complete | Cumulative |
| 10/28/12 | 751 | 258 | 28 | 10 | 455 | $32,825 | $32,825 | 2.8% | 164 |
| 02/24/13 | 11,726 | 945 | 482 | 284 | 10,015 | $578,399 | $612,224 | 51.6% | 194 |
| 03/31/13 | 18,167 | 1,168 | 528 | 835 | 15,636 | $209,106 | $821,330 | 69.2% | 226 |
| 04/28/13 | 22,449 | 1,318 | 586 | 1,024 | 19,541 | $155,832 | $977,162 | 82.4% | 237 |
| 05/26/13 | 25,319 | 1,479 | 604 | 1,121 | 22,115 | $74,353 | $1,051,515 | 88.6% | 250 |
| 06/30/13 | 27,595 | 1,680 | 650 | 1,147 | 24,519 | $92,896 | $1,144,412 | 96.4% | 254 |
| 07/28/13 | 29,801 | 1,861 | 688 | 1,273 | 25,980 | $21,086 | $1,165,499 | 98.2% | 264 |
| 08/31/13 | 30,382 | 2,066 | 737 | 1,429 | 26,151 | $21,087 | $1,186,585 | 100.0% | 262 |
| Total | | | | | | | $1,186,585 | | |

**Loss of Productivity Calculation**

| | | | | Measured Mile | | Impact Period | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Start to 2/24/13 | | 2/25/13 to 8/31/13 | | | |
| Man-hours Expended | | | | 10,015 | | 16,136 | | | 26,151 |
| Base Contract Dollars Earned | | | | $612,224 | | $574,361 | | | $1,186,585 |
| Earned Percent Complete | | | | 51.6% | | 48.4% | | | 100.0% |
| Man-hours/ 1 % Earned | | | | 194 | | 333 | | | |
| Less Measured Mile | | | | | | (194) | | | |
| Net Impact per 1 % Complete | | | | | | 139 | | | |
| Portion of Project Impacted | | | | | | 48.4% | | | |
| Added Impact Hours | | | | | | 6,728 | | | 6,728 |

## Disputes




| | |
|---|---|
| Added Labor Cost | $384,580.00 |
| Premium Time | $17,770.00 |
| Supervision | $91,735.00 |
| General Conditions | $33,501.00 |
| Home Office Support | $69,615.00 |
| Less: 2nd Shift Premium in Bid | ($23,740.00) |
| Total | $573,461.00 |

| | |
|---|---|
| Original Contract Amount | $3,486,140.00 |
| Executed Change Orders | $301,699.53 |
| Agreed Upon Adjusted Contract | $3,787,839.53 |
| Amount Paid to Date as of May 21, 2014 | $3,508,163.70 |
| Agreed Upon Contract Balance | $279,675.83 |
| Pending Change Orders | $7,975.59 |
| Total Contract Balance and Disputed Direct Costs | **$287,651.42** |

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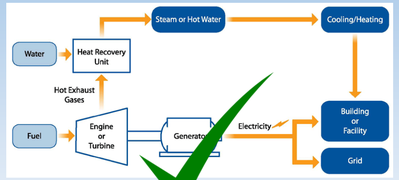
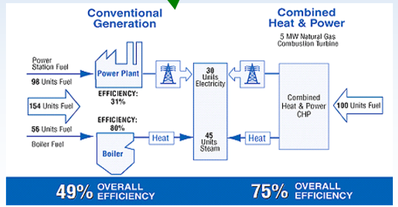
# Final Recommendations Based On Analyses

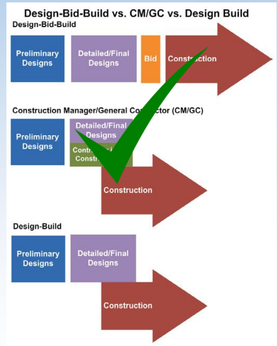
## Breadth 1: Power Interconnect & Black Start Capability

## Depth: Cogeneration Plant Implementation




## Breadth 2: Alternate Project Delivery System



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# Acknowledgements


| | |
|---|---|
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| Jim Rankin | Asst. Dir. of Campus Operations- Northeast Ohio Medical University |
| Jim Freihaut | Professor of Architectural Engineering – Penn State |
| Rob Leicht | Asst. Professor of Architectural Engineering – Penn State |
| Tim Warren | President - JDB Engineering, Inc. |
| Tom Leary | Executive VP/DOP - JDB Engineering, Inc. |
| Ari Tinkoff | Managing Director/Principal - BR+A Consulting Engineers |
| Scott Walthour | Managing Principal – Arium AE |
| Chris Elgin | Structural Engineer - GPD Group |
| Diet Mt. Dew | Carbonated Soft Drink – PepsiCo Inc. |
| Steam | Internet-based gaming platform – Valve Corporation |