


# DOE Energy Storage Systems Research Program Annual Peer Review

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## Design of the FESS 20 MW Frequency Regulation Plant


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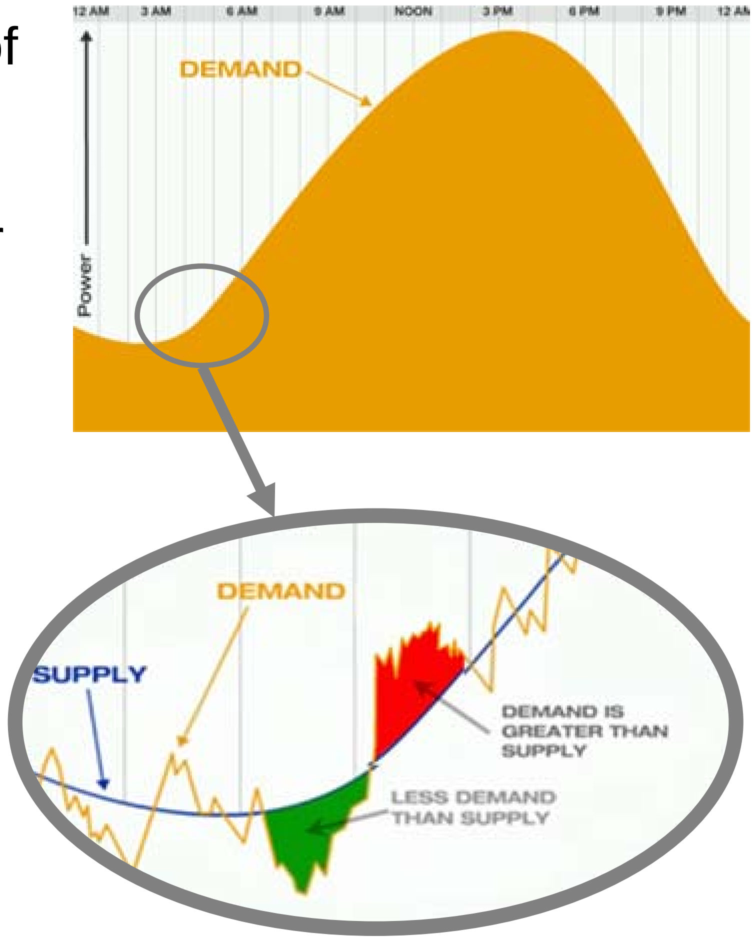
# Frequency Regulation

*Benefit of Flywheel Based Frequency Regulation*

## Increases the Reliability and Stability of the Grid

- Frees up generator capacity
- Fast response may reduce quantity of necessary frequency regulation
- Increases market competition
- Benefit for deployment of wind power

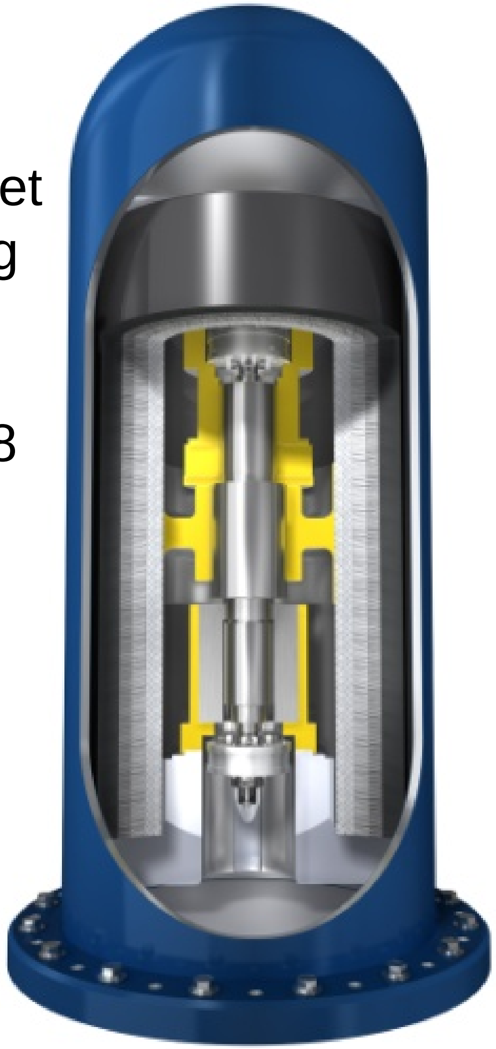



## Environmental

- No direct fossil fuel consumption
- Zero plant emissions

## Beacon's Market Strategy

- Sell frequency regulation service
- Provide services via deregulated open-bid market
- Qualified with scale-power demonstration testing
- Commercialize with 25 kWh Gen 4 flywheel
- 1st service revenues in April 2008 (1 MW)
- 10 to 20 MW of service revenues by end of 2008



Beacon Power's
Gen4 Flywheel

# Sandia Contract Key Deliverables



Technology Comparison

- Emissions Analysis
- Cost to Provide Regulation Analysis

Development of 20 MW FR Plant Drawing Package

- Building designs and layouts
- Subsystem design
- Investigate LEED-NC rating

# Technology Comparison

*Cost Performance Analysis – Assumptions*

## Technology Comparison

- Emissions Analysis – Presented on Monday Sept 24 by KEMA
- Cost performance analysis
  - Determine the cost to provide regulation for competing technologies
    - Flywheel
    - Battery
    - Natural gas fired baseline and peaker plants
    - Coal fired baseline and peaker plants
  - Cost areas include
    - Plant first cost
    - Maintenance cost
    - Fuel and electricity costs
    - Emissions cost

# Technology Comparison

*Assumptions (Continued)*

## Coal and Natural Gas 400 MW base loaded power plants

- Provide $\pm 20$ MW regulation, or 5% of load
- Already participating in the market producing energy
- Constant cycling reduces efficiency

## Coal and Natural Gas 75 MW peaker plants

- Provide $\pm 20$ MW regulation
- Typically operational for six to eight hours a day
- Running lower efficiencies when below peak power

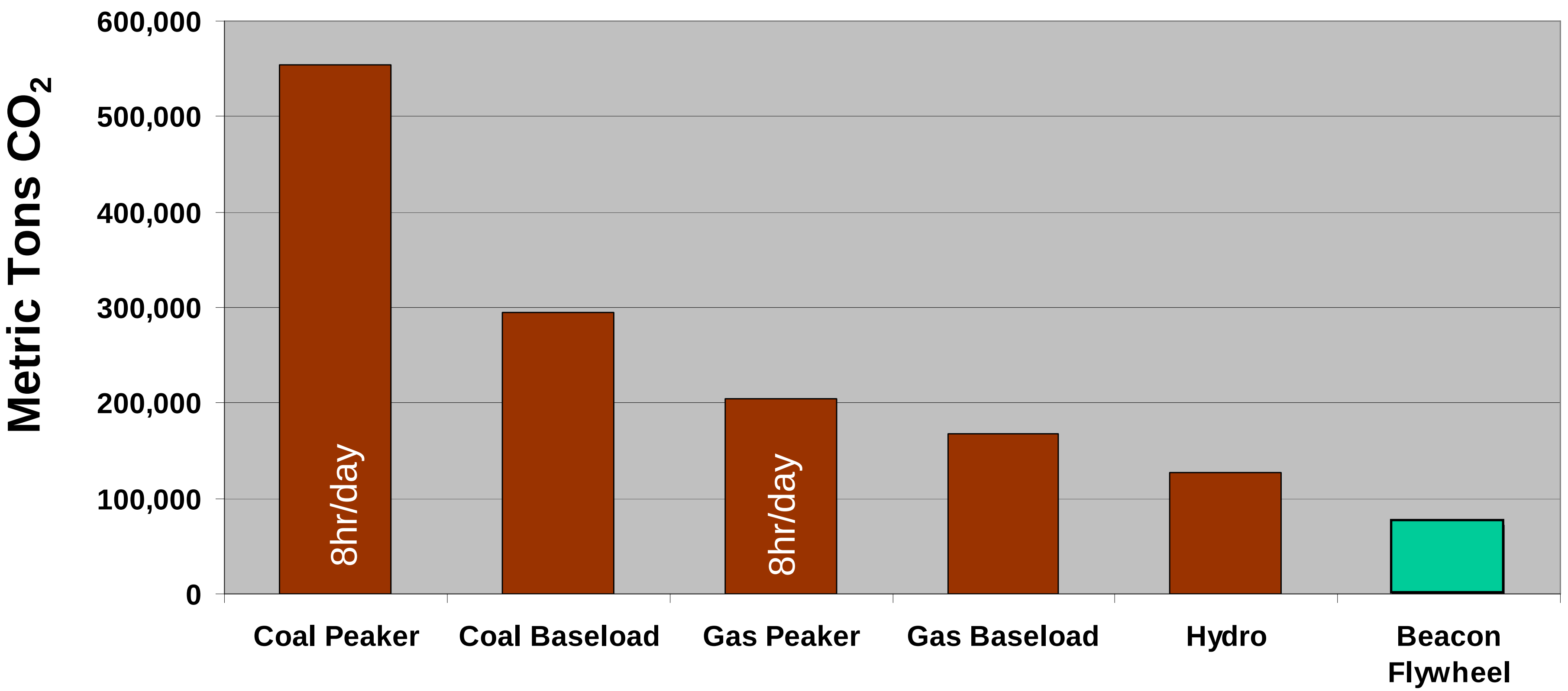
## Flywheel and Battery 20 MW plants

- Provide $\pm 20$ MW regulation
- Operational 24 hours a day
- Flywheel performance not affected by cycling

# Technology Comparison - Emissions

*$CO_2$ Reduction*

**From KEMA study: 20 MW of Regulation over 20-year operating life**




Dramatic reduction in $CO_2$ emissions vs. present methods

# Technology Comparison

*Cost Performance Analysis – Assumptions*

KEMA cost performance analysis estimated the ***cost for generators to provide*** frequency regulation.

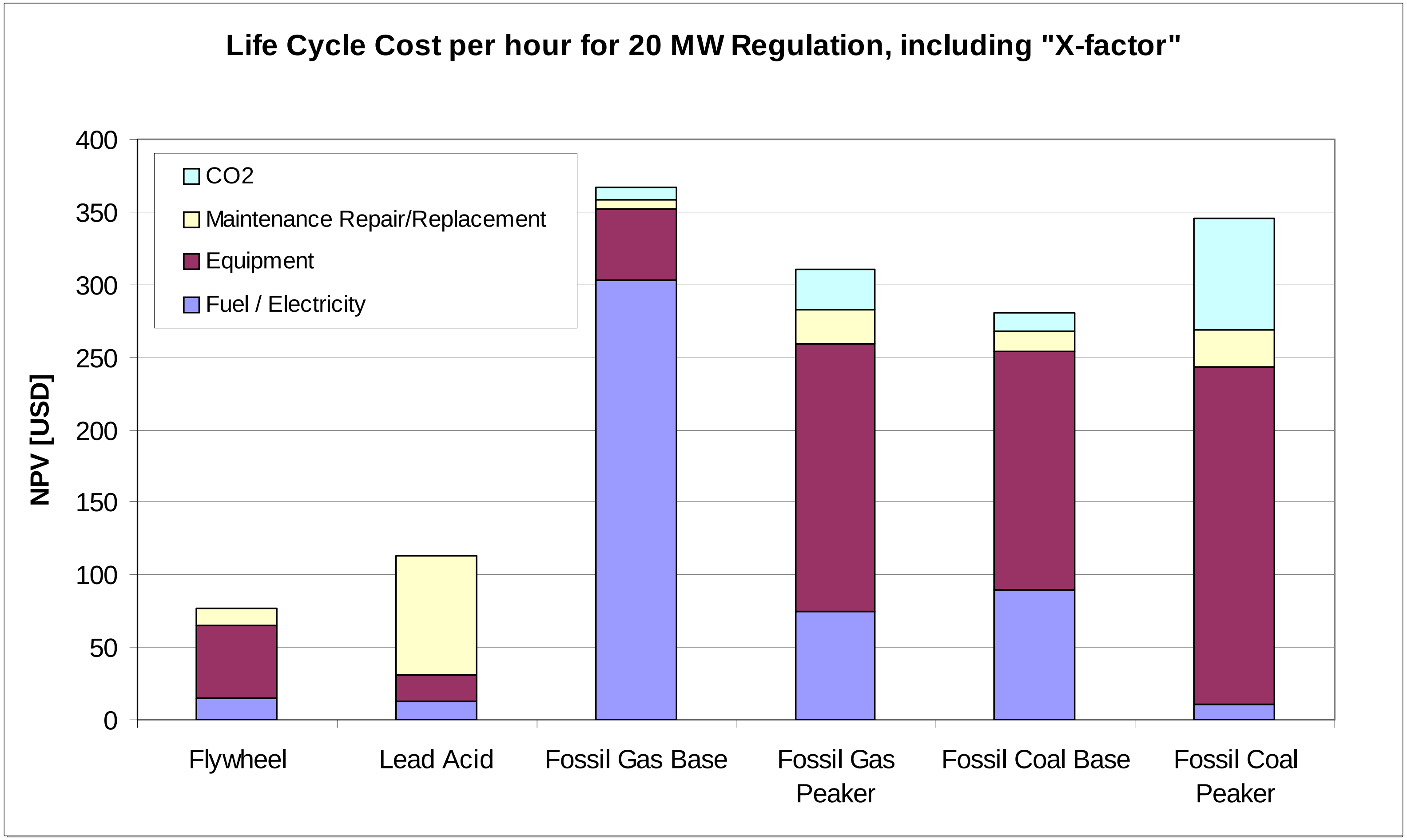
## Cost Assumptions

- 30 Year life - Net Present Value with 7.5% discount rate
- Negative impact due to providing regulation
  - 12 to17 trips per year expected
  - Reduced availability
  - Reduces plant life by approximately 1 year
  - 1 to 2 million Euros per year additional maintenance
- Battery data from EPRI-DoE Handbook
- Fossil fuel data from public domain and KEMA experience

# Technology Comparison

*Cost Comparison - Results*

## Cost model results per hour

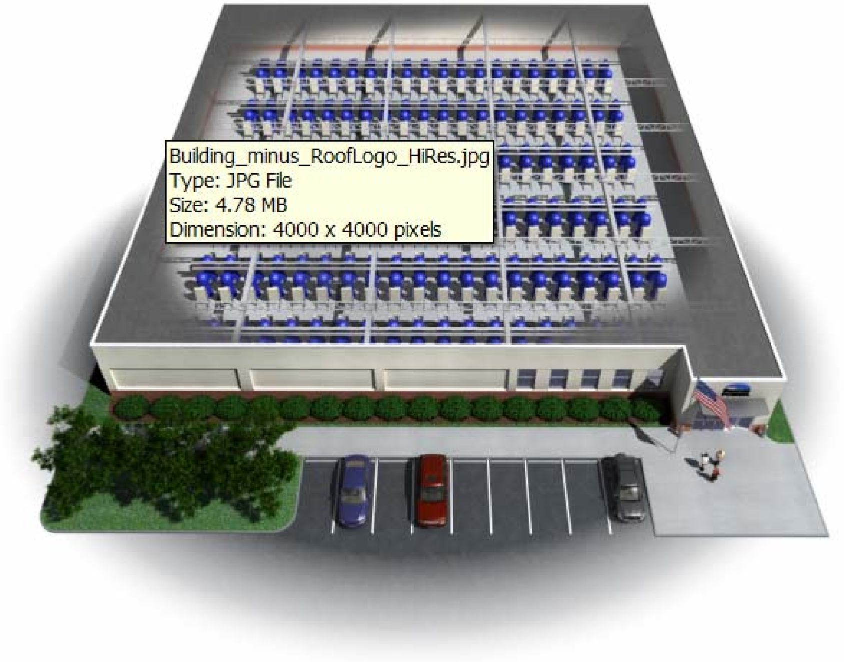


# Design of the 20 MW FESS Plant

*Assumptions*

## Building

– Simple generic design
– Evaluate LEED-NC rating
– Evaluate PV to make up for system losses
– Minimize AC and heating load
– Operational 24 hours a day
– Minimize operational and capital costs




## Process Cooling System

– Radiator based ECM cooling loop
– Chiller based flywheel cooling loop
– High level of system reliability

## Electrical System

– One 20 MVA transformer
– Ten ~2 MVA transformers

# FESS Regulation Building

*Rendering*

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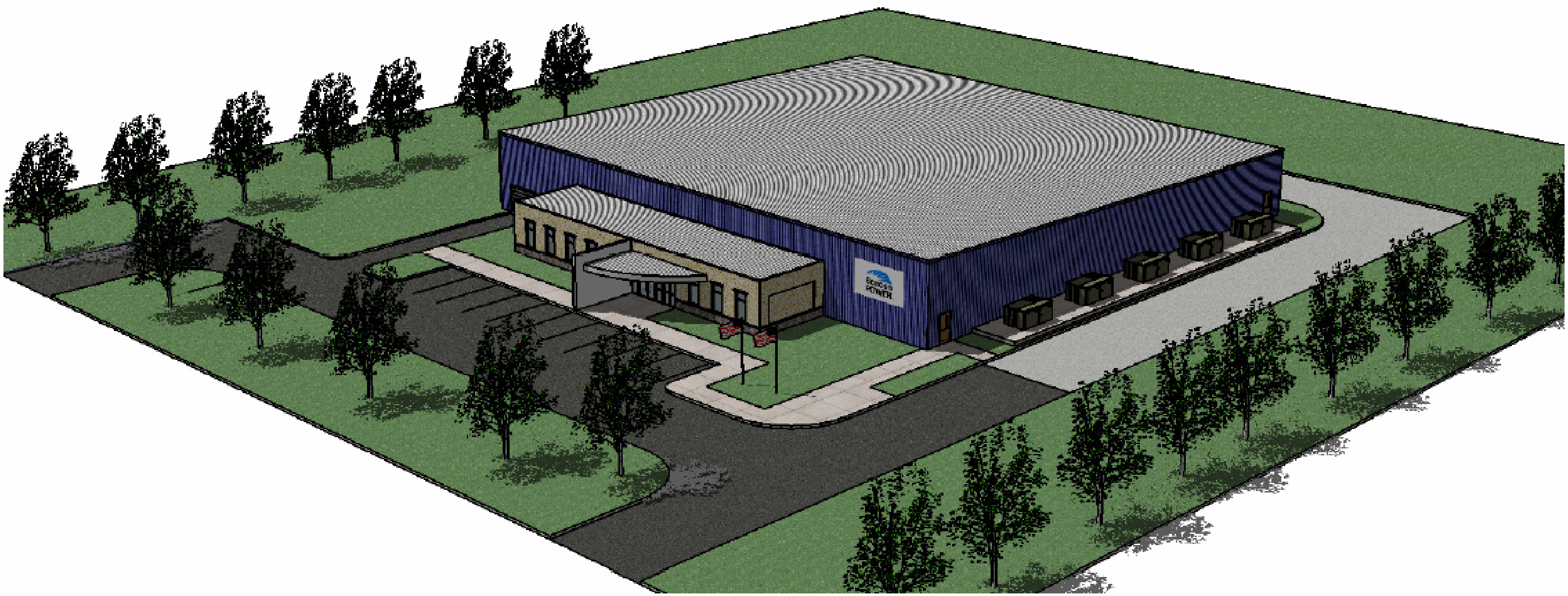
## 20 MW Plant containing 200 Flywheels

- Generic building design with a footprint of 22,400 $ft^2$
  - 20,600 $ft^2$ Flywheel plant
  - 1,800 $ft^2$ Office/Conference/Storage Area $ft^2$
- Simple construction allows for pre-engineered buildings
- Can be built without local water and sewer



# FESS Regulation Building

*Elevations*

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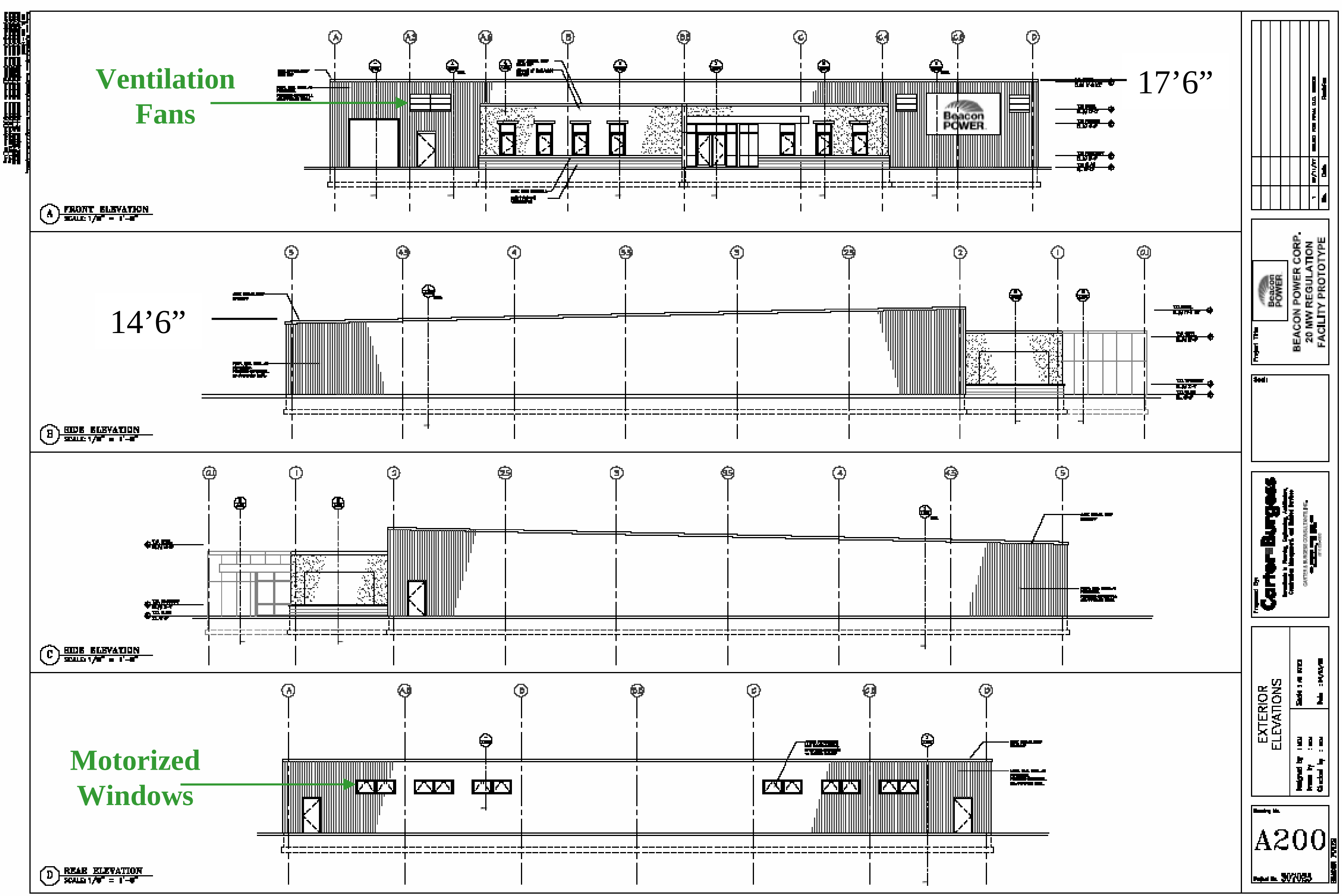
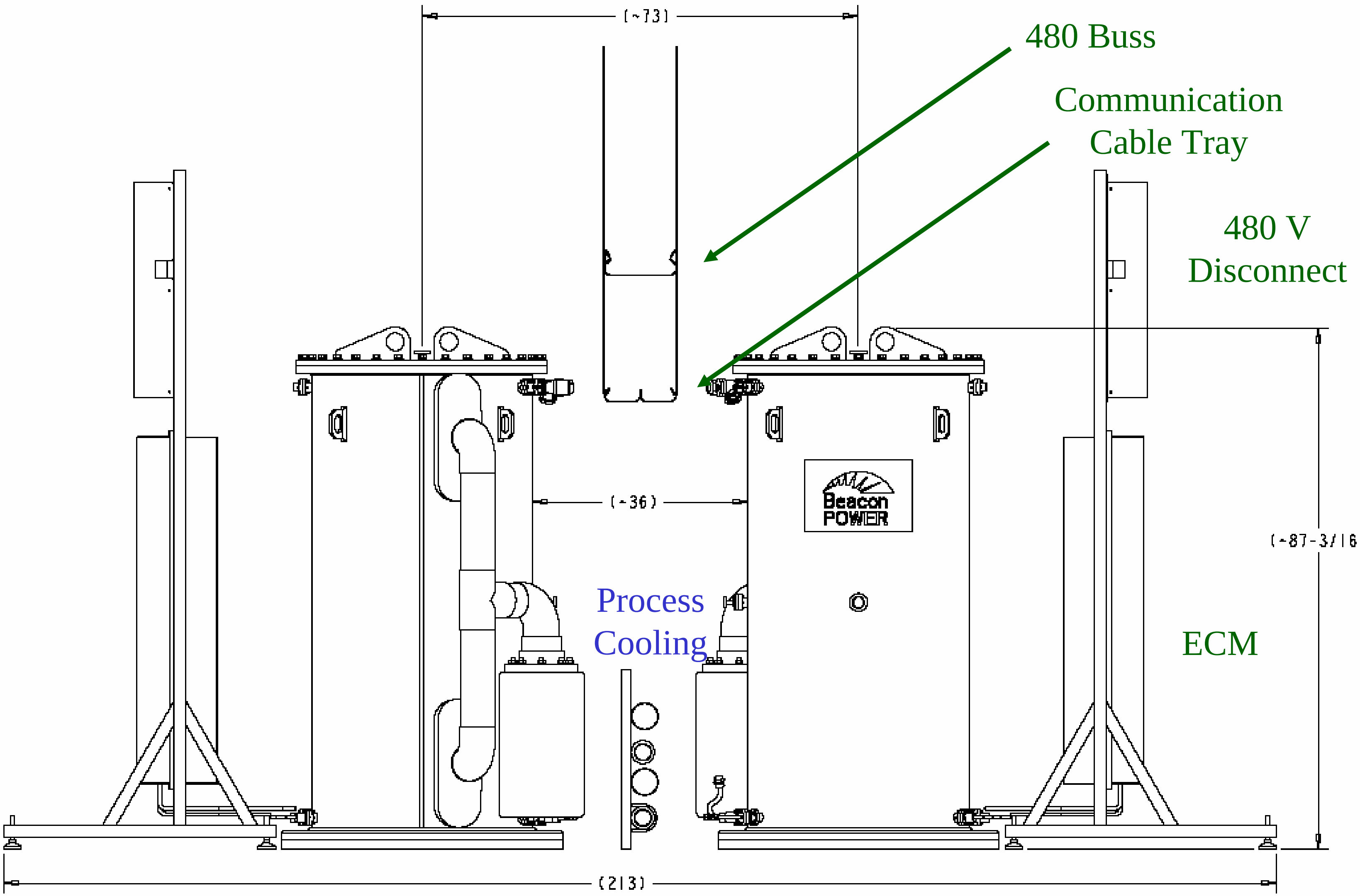


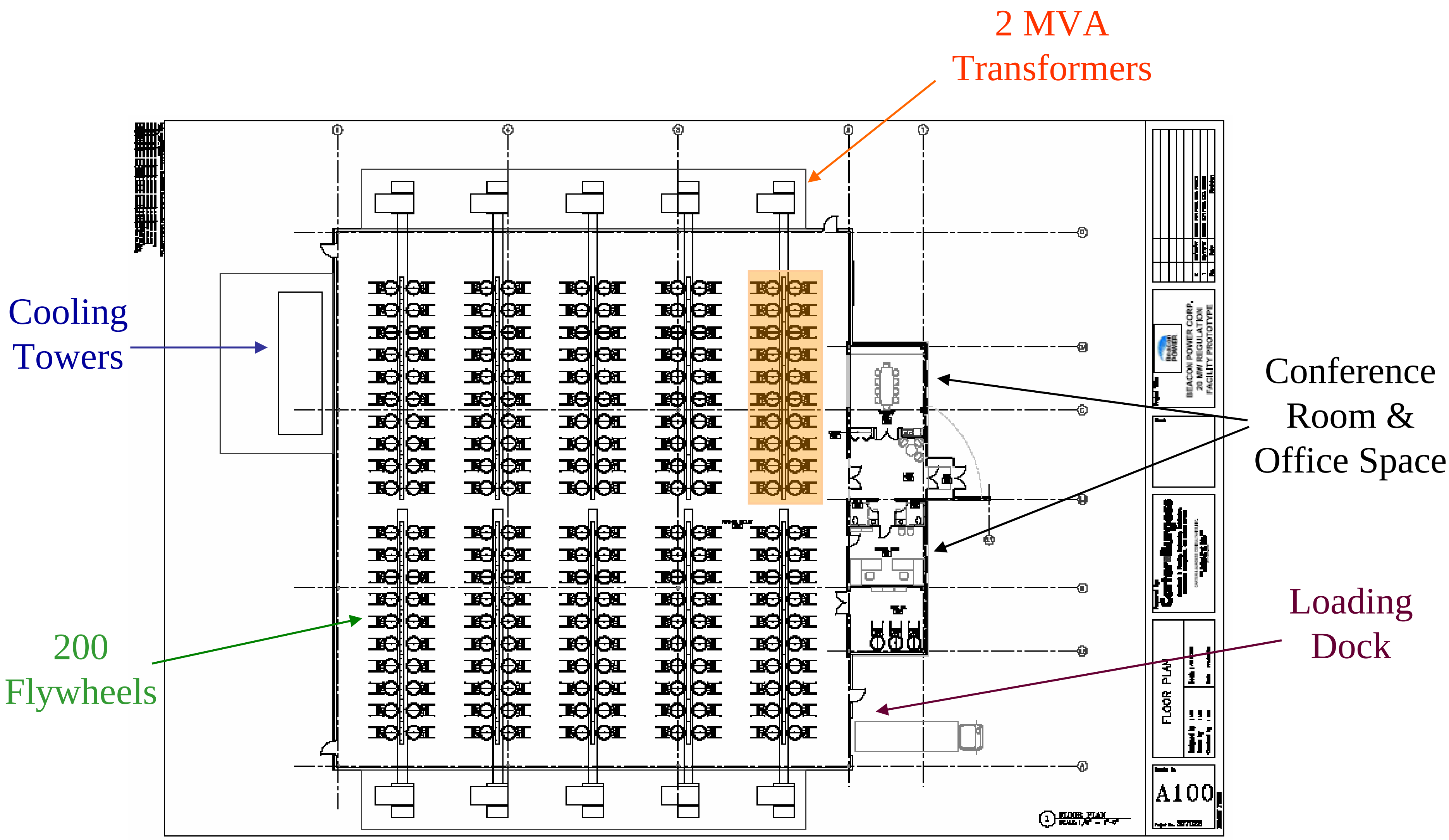
# Flywheel Layout

*Side View of Flywheels*



# Plant Layout

*Top View*



# Site Layout

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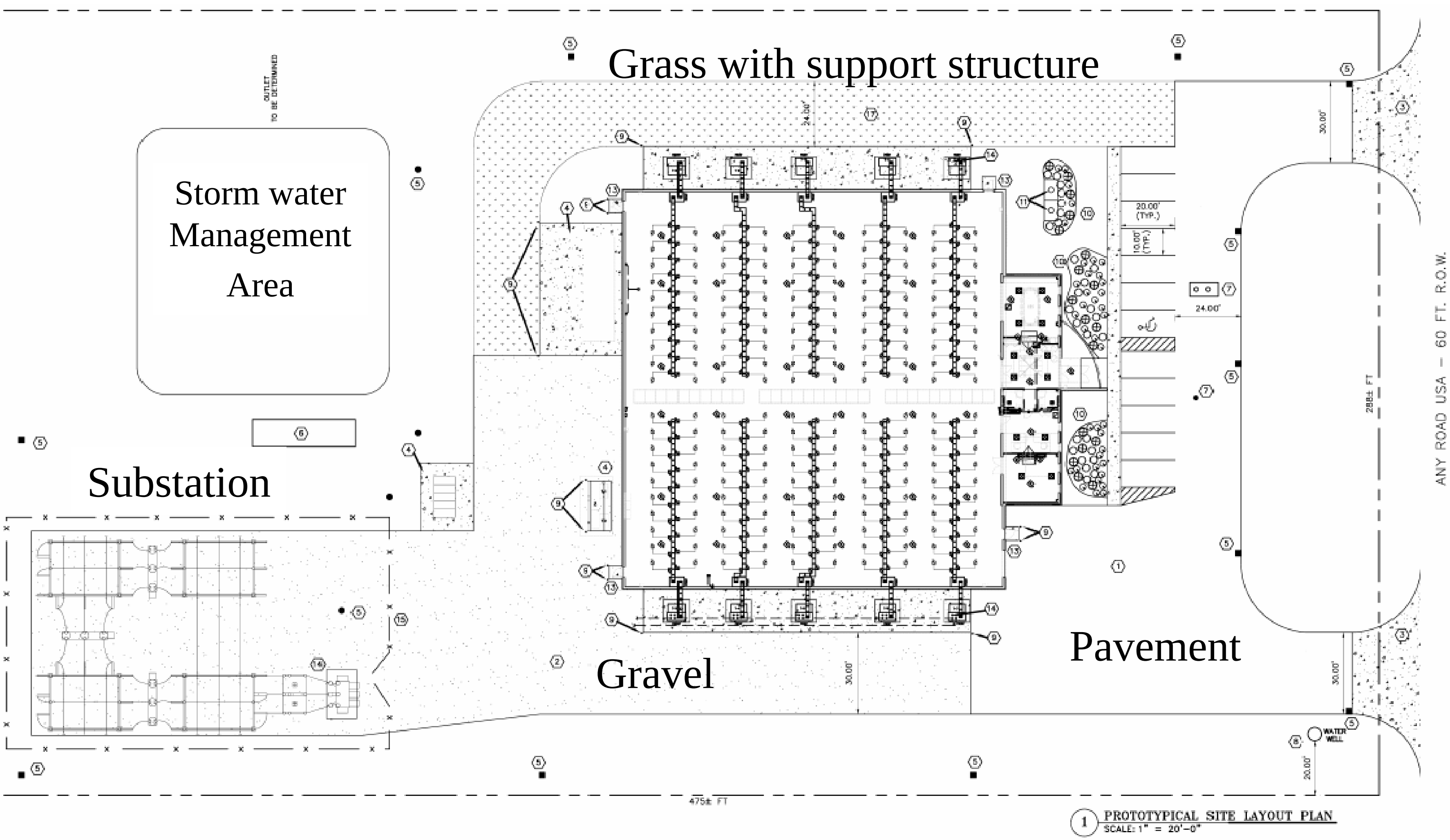
## Stand alone site layout without city services



# LEED-NC Certification

*Leeds Comparison*

## LEED for New Construction v2.2
## Registered Project Checklist

| | Potential Points | Yes | ? | No |
|---|---|---|---|---|
| Sustainable Sites | 14 Points | 8 | 1 | 5 |
| Water Efficiency | 5 Points | 3 | 2 | 0 |
| Energy & Atmosphere | 17 Points | 6 | 1 | 10 |
| Materials & Resources | 13 Points | 6 | 3 | 4 |
| Indoor Environmental Quality | 15 Points | 9 | 3 | 3 |
| Innovation & Design Process | 5 Points | 1 | 0 | 4 |
| **Project Totals** (pre-certification estimates) | 69 Points | 33 | 10 | 26 |

| LEED-NC Ratings | |
|---|---|
| **Platinum:** | 52-69 points |
| **Gold:** | 39-51 points |
| **Silver:** | 33-38 points |
| **Certified:** | 26-32 points |

LEED-NC Silver attainable with a potential to reach Gold

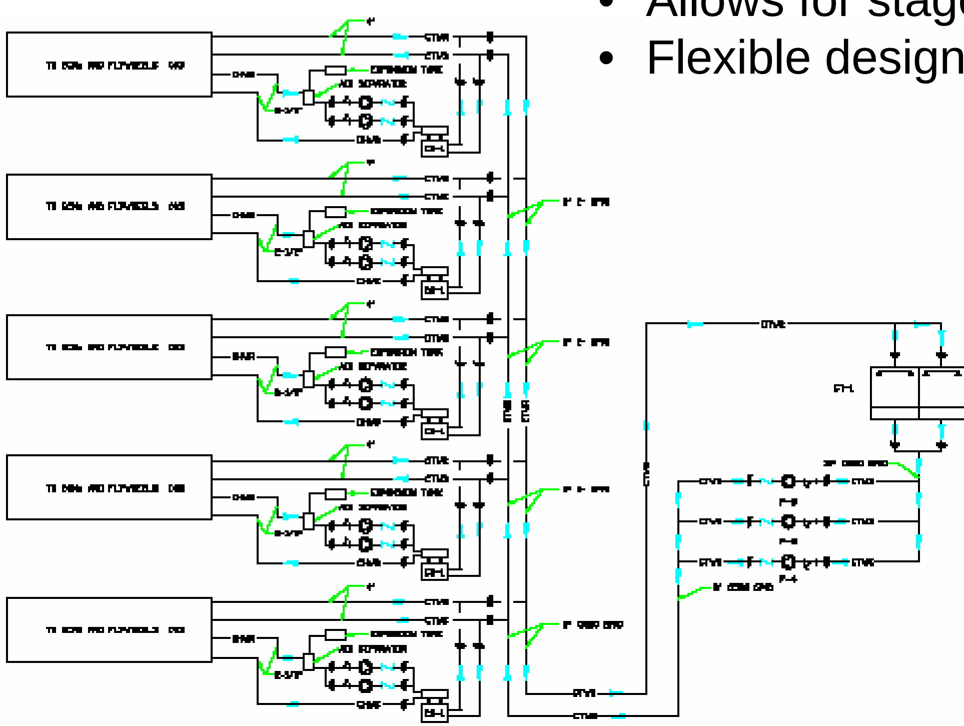
# Process Cooling Design

## Design Criteria

- High temperature loop
- Low temperature loop
- Low maintenance
- Optimize performance

## Two Design Approaches

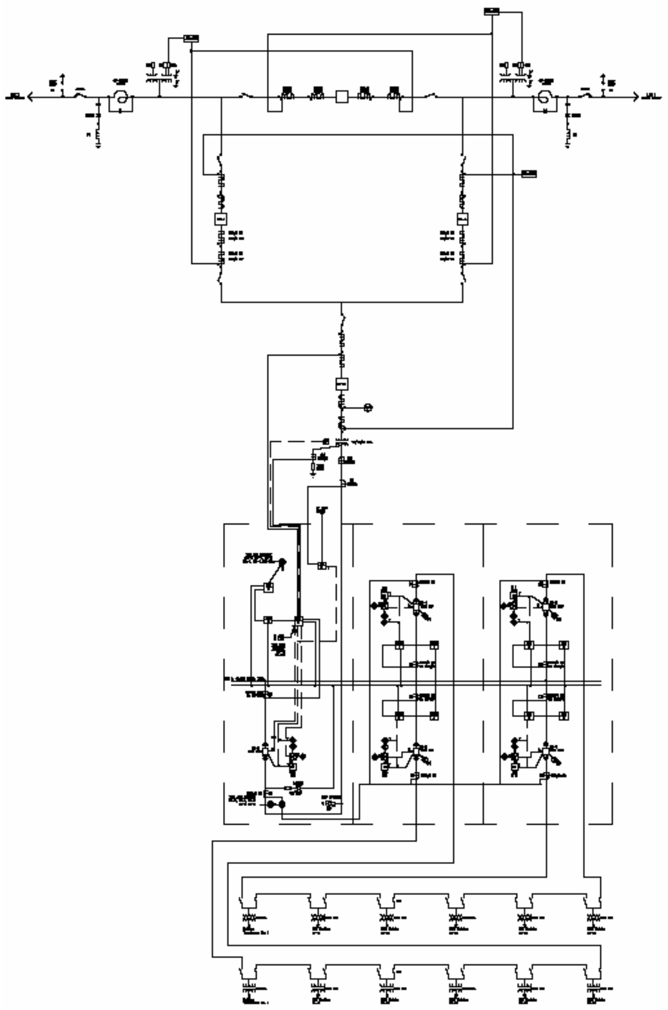
- Centralized chiller room
  - More efficient design
- Modular Design
  - Higher redundancy for same cost
  - Allows for staged occupancy
  - Flexible design for 4 MW blocks



# Electrical One Line Diagram

Transmission line Interconnection

- Single 20 MVA transformer
- Connect from 13.8 kV to 115 kV
- 10 2MVA transformers 480 V to 13.8 kV
- Fault tolerant design



# Site Selection Criteria

Optimal site characteristics for new construction

- – Close proximity to unconstrained transmission substation
- – Inexpensive land
- – Low electricity prices

| | |
|---|---|
| Site Topography: | Minimal grade change throughout site. |
| Available Utilities: | Public Storm drain<br>Public Sanitary connection<br>Public Water connection<br>Telephone |
| Zoning: | Industrial / Light Manufacturing –Typical. Allow for construction of facility without requiring rezoning, variances, etc. In some situations, actually only require administrative review by municipality |
| Parcel: | Vacant. No demolition / site preparation required. |
| Geotechnical: | Suitable bearing capacity without "over cutting". Material could also allow for infiltration of storm water if acceptable my municipality. |
| Municipal Requirements: | Minor relative to landscaping, screenings, building materials, etc. |

# PV Assessment

*Evaluated Two Potential Sites*

Evaluate the use of PV to recover plant energy losses

- Sized for maximum roof coverage
- Compared fixed vs. Single axis tracking
- Evaluated potential energy generation for two US sites
  - Southern California
  - Central MA

| | Fixed Array | Single Axis |
|---|---|---|
| Southern California | 1.8% | 2.3% |
| Central Massachusetts | 1.5% | 1.8% |

# Design Lessons Learned

Results of design process

- Defined major areas that may be needed to be developed
  - Equipment required for substation
  - Land requirements if no city and septic and sewage are available
- Defined optimal process cooling specifications
- Completed plant one-line diagram
  - Needed for interconnection process
  - To determine cost/reliability
- Performed cost reduction of site/building design
- Performed cost reduction steps taken for building

"Plant style" design cost estimated to be $10 to $12 million

Initiated "substation style" design to reach $5 million goal

# Prefab Construction

*Cost Performance Analysis – Assumptions*

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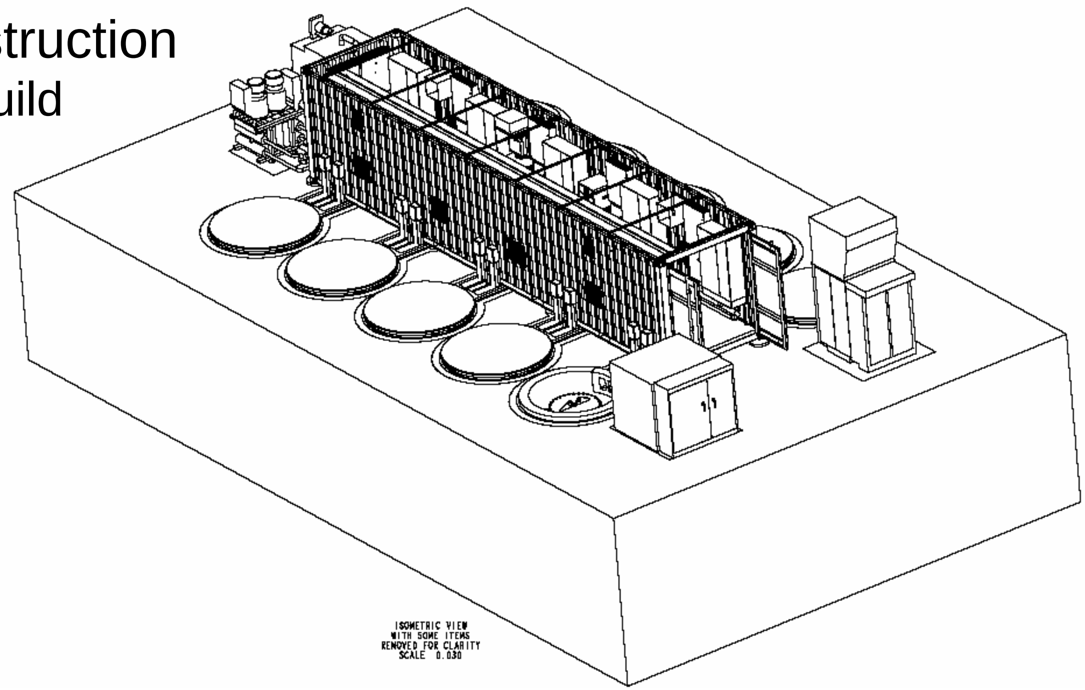
## Outdoor Substation Style Design

- Flywheels mounted in pre-cast housings
- Factory built MW module to provide
  - Plumbing
  - Electrical
  - Communications
- Minimal onsite construction
- Reduce timeline for build



# Prefab Construction

*Profile View*

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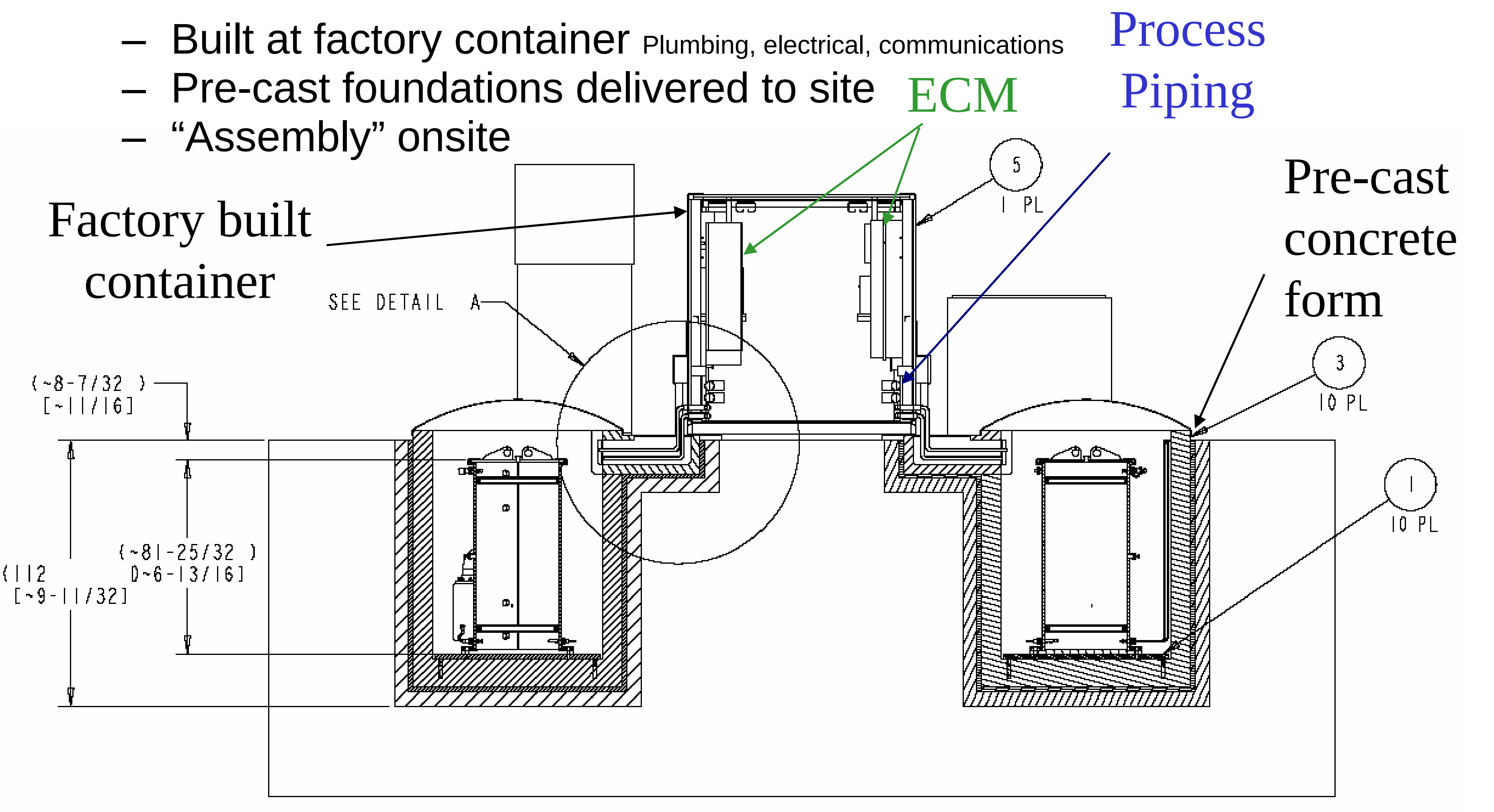
## Facility Development Goals

- Built at factory container Plumbing, electrical, communications
- Pre-cast foundations delivered to site
- “Assembly” onsite

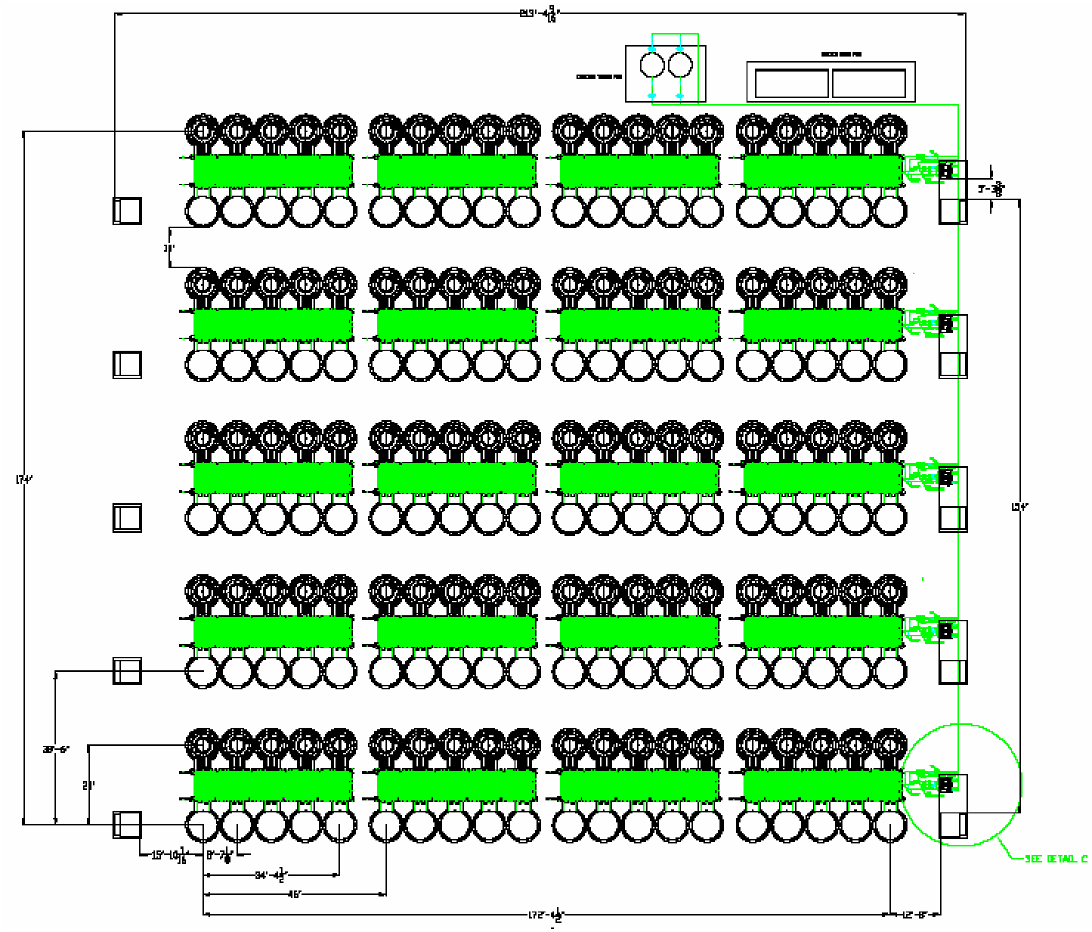


# Prefab Construction

*Site Layout*

## Utilizes Designs Developed in Sandia Project

- Plant layout
- Process Piping
- Electrical Layout




## Potential Savings

- Site costs
- Construction Time
- Required land

# Next Steps

Sandia contract

– Final report on plant style design to be issued by: bla

Complete prefab derivative design

– Design work will continue after Sandia contract completion
– Complete engineering design
– Design factory built modules
– Hire contracting firm to provide site engineered drawings

First commercial plant (1 MW)

– Procure and assemble flywheels
– Procure support module
– Demonstrate system performance
– Install on site (April 2008)

# Thanks

## Thanks again to:

Imre Gyuk
*Program Manager*
*Energy Storage Research*
*Department of Energy*

Georgianne H. Peek
*Project Manager*
*Electrical Energy Storage and*
*Distributed Energy Resources*
*Sandia National Laboratories*

Garth Corey
*Electrical Energy Storage and*
*Distributed Energy Resources*
*Sandia National Laboratories*

## Additional thanks to:

- Carter Burgess Consulting
- Richard C. Gross PE Inc.
- KEMA Consulting

# Design Build – Process Piping

*Cost Performance Analysis – Assumptions*

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## Centralized vs. Modular Process Cooling

| | Central Chiller Design | Modular Chiller Design |
|---|---|---|
| **First Cost** | Similar first cost on the chillers, higher piping cost if there is no common line to tie distribution chillers together. | Similar first cost on the chillers, higher construction cost due to bigger floor space required. |
| **Maintenance** | Shell and tube heat exchangers will require less cleaning cycles than the plate and frame heat exchangers associated with the Multi-stack options. Screw compressors require minimal maintenance. | More maintenance work required than the central plant due to more machines (chillers, pumps, etc) and the difference in heat exchangers. |
| **Floor Area** | Requires a central mechanical room | Requires more floor space in flywheel area. Chillers will be mingled with flywheels. Requires expansion of flywheel area. |
| **Redundancy** | 2 chillers each at 60% total design load and each chiller has 2 screw compressors. | There will be 5 distribution chillers to meet 100% total design load and each serving one row of flywheels. One chiller will have two scroll compressors. Higher redundancy if chiller loops are tied together. |
| **Efficiency** | similar | |
| **Water treatment requirements** | Low. | The plate heat exchangers will require a higher level of demineralization to reduce scale on the plates than the shell and tube heat exchangers of the central plant option. |