MARQUETTE ENERGY CENTER (MEC)
52MW DUEL FUEL RECIPROCATING ENGINE POWER PLANT
DESIGN CONSIDERATIONS AND FEATURES
About the Speaker

Chuck Beitel
Project Director and Vice President
Sargent & Lundy LLC

- 24 Years in Power Industry Covering New Generation, Environmental, and Station Services Projects
- B.S. Mechanical Engineering – University of Missouri, Columbia
- PM for Marquette New Generation Study Project
- Director for Detailed Engineering for MEC
- 100 MW of Other Active Recip Projects Ongoing
Sargent & Lundy Company Profile

- Headquartered in Chicago, Illinois
- Power Industry Focus: All Aspects of New Generation, Distribution, Environmental, and Services Projects
- ISO 9001:2015 Certified Quality System
- 2,220+ staff members
- Annual revenue in excess of $500M
- Consistently ranked in Top Five by Engineering News-Record magazine in Global Power Sector (#4 in May 2017)

Providing Project Management, Engineering, Design, and Consulting Services to Power Generation and Power Delivery Industries

Headquarters: 55 East Monroe Street, Chicago, Illinois
CURRENT ACTIVITIES – NEW GENERATION

RECENT RICE ACTIVITY

- Marquette Board of Light & Power
  » Marquette Energy Center (3 × 18 MW)
- City of Tallahassee
  » Substation 12 (2 × 9 MW)
  » Hopkins RICE (4 × 18 MW)
- Montana-Dakota Utilities
  » Lewis & Clark RICE (2 × 9 MW)
- Rochester Public Utilities
  » Westside Energy Station (5 × 9 MW)
- Tucson Electric Power
  » Tech Support for New 10 × 18 MW Facility

OTHER NOTABLE NEW GEN. PROJECTS

- Gemma Power Systems / NTE Energy
  » Middletown Energy Center (475 MW)
  » King’s Mountain Energy Center (475 MW)
- Abeinsa / Portland General Electric
  » Carty Combined Cycle (450 MW)
- Old Dominion Electric Cooperative
  » Wildcat Point Combined Cycle (1000 MW)
- Samsung Engineering
  » Balkhash Coal Plant (1,200 MW)
Marquette Energy Center (MEC)
Background Information
Marquette Board of Light and Power (MBLP)
**Characteristics of Pre-Existing MBLP Resources**

<table>
<thead>
<tr>
<th>Resources</th>
<th>Capacity (MW)</th>
<th>Heat Rate (Btu/kWh)</th>
<th>Utilization</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shiras 3</td>
<td>39.9</td>
<td>13,300</td>
<td>Baseload</td>
<td>32</td>
</tr>
<tr>
<td>Shiras 2</td>
<td>16.1</td>
<td>14,000</td>
<td>Baseload or Intermediate</td>
<td>44</td>
</tr>
<tr>
<td>MBLP CT</td>
<td>20</td>
<td>13,600</td>
<td>Peaking</td>
<td>36</td>
</tr>
</tbody>
</table>

- Coal fired units of the age of Units 2 and 3 and older often require increased investment to maintain the unit in reliable operating condition.
- Current portfolio exhibits higher heat rates
- Table does not include purchase power resources - availability of firm import capability in the future was uncertain at the time of study
Establishing Generation Expansion Design Basis

3 Considerations for Generation Planning – Reliability, Reliability, Reliability:

• Potential near term retirement / forced outages of the WE Energies Presque Isle Power Plant.
• Increasingly constrained transmission import capability
• Potential unplanned outages on Shiras Unit 3.
• Uncertainly regarding 345KV transmission system expansion plans by external parties (ATC, WE Energies)
• Decreased availability of existing MBLP generating assets
• All of these presented risks to the reliability of power supply

A Strong Desire to Not Rely on Yet to be Defined Future Actions By Outside Parties (e.g. ATC, WE Energies) Drove Action by MBLP.
Defining Characteristics of the Next MBLP Capacity Addition

- **Low Heat Rate** - Current technologies can provide heat rates under 9,000 Btu/kWh.
- **Expandable** - Choose a technology that can be expanded as needed to meet load growth or to replace the capacity in the future.
- **Dual Fuel** - Provide the capability to use on-site fuel oil if gas supply is constrained in MBLP service territory.
- **Black Start** - Provide the capability or the ability to add this capability when the MBLP Combustion Turbine is retired.
- **Quick Start** - Provide a capability to go from start to full load in as low as two to five minutes.
Potential Co-Benefits to the Reliability Driver

- **Provide Long Term Flexibility (30+ Years)**
  - Hedge Against Purchased Power Prices Increases / Spikes
  - Newer Flexible Power Options Provides Option to Shut Down Quickly and Shop Around During Non-Peak Times

- **Keep $$ Local**
  - Workforce Retention and Corresponding Economic Benefit
  - Retain Payment In Lieu of Taxes (PILT) Provided by Self Generation

- **Provide a Foundation for Future Renewables**
### Comprehensive Initial Technology Screening – Included CTs, Recips, Combined Cycle and Repowering

<table>
<thead>
<tr>
<th>Technology</th>
<th>New Generation</th>
<th>OEM</th>
<th>Fuel Type</th>
<th>Config.</th>
<th>Approx. Output (kW)</th>
<th>Approx. Heat Rate, HHV (Btu/kWh)</th>
<th>Number of Machines</th>
<th>Other Present Additions</th>
<th>Expansion Opportunity for Load Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTG</td>
<td>LM1800e</td>
<td>GE</td>
<td>NG</td>
<td>SC</td>
<td>17,600</td>
<td>10,740</td>
<td>2</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>CTG</td>
<td>LM1800e</td>
<td>GE</td>
<td>NG</td>
<td>CC</td>
<td>24,800</td>
<td>7,900</td>
<td>1</td>
<td>NONE</td>
<td>Install RICE 10 to 15 MW</td>
</tr>
<tr>
<td>CTG</td>
<td>LM2500PJ</td>
<td>GE</td>
<td>NG</td>
<td>SC</td>
<td>23,300</td>
<td>10,350</td>
<td>1</td>
<td>NONE</td>
<td>Install RICE 10 to 15 MW</td>
</tr>
<tr>
<td>CTG</td>
<td>LM2500PJ</td>
<td>GE</td>
<td>NG</td>
<td>CC</td>
<td>33,400</td>
<td>7,230</td>
<td>1</td>
<td>Repower Unit 2</td>
<td>Repower Unit 2 (5 - 7 MW on Unit 2 STG, ~29,000 kW at 8,300 Btu/kWh)</td>
</tr>
<tr>
<td>CTG</td>
<td>LM6000PF</td>
<td>GE</td>
<td>NG</td>
<td>SC</td>
<td>44,500</td>
<td>9,080</td>
<td>1</td>
<td>NONE</td>
<td>Future CC Expansion</td>
</tr>
<tr>
<td>CTG</td>
<td>LM6000PF</td>
<td>GE</td>
<td>NG</td>
<td>CC</td>
<td>58,100</td>
<td>6,950</td>
<td>1</td>
<td>Repower Unit 2</td>
<td>Repower Unit 2 (10.6 MW on Unit 2 STG, ~50,500 kW at 7,560 Btu/kWh)</td>
</tr>
<tr>
<td>CTG</td>
<td>SGT-400</td>
<td>Siemens</td>
<td>NG</td>
<td>SC</td>
<td>14,300</td>
<td>10,710</td>
<td>2</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>CTG</td>
<td>SGT-800</td>
<td>Siemens</td>
<td>NG</td>
<td>SC</td>
<td>50,000</td>
<td>10,000</td>
<td>1</td>
<td>NONE</td>
<td>Future CC Expansion</td>
</tr>
<tr>
<td>CTG</td>
<td>SCC-800</td>
<td>Siemens</td>
<td>NG</td>
<td>CC</td>
<td>70,500</td>
<td>6,920</td>
<td>1</td>
<td>Repower Unit 2</td>
<td>Repower Unit 2 (17.3 MW on Unit 2 STG, ~63,700 kW at 7,630 Btu/kWh)</td>
</tr>
<tr>
<td>CTG</td>
<td>Titan 130</td>
<td>Solar</td>
<td>NG</td>
<td>SC</td>
<td>15,000</td>
<td>10,760</td>
<td>2</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>CTG</td>
<td>Titan 250</td>
<td>Solar</td>
<td>NG</td>
<td>SC</td>
<td>21,700</td>
<td>9,740</td>
<td>2</td>
<td>Install RICE ~10 MW</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>RICE *</td>
<td>18V50DF</td>
<td>Wärtsilä</td>
<td>NG</td>
<td>SC</td>
<td>16,600</td>
<td>8,470</td>
<td>2</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>RICE *</td>
<td>16CM43</td>
<td>Caterpillar</td>
<td>NG</td>
<td>SC</td>
<td>14,040</td>
<td>8,375</td>
<td>2</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
<tr>
<td>RICE *</td>
<td>G20CM34</td>
<td>Caterpillar</td>
<td>NG</td>
<td>SC</td>
<td>9,700</td>
<td>8,480</td>
<td>3</td>
<td>NONE</td>
<td>Add additional machine(s)</td>
</tr>
</tbody>
</table>

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Considerations for Refining the Generation Options

- Undesirable heat rate eliminated smaller CT options in simple cycle (LM1800, LM2500, SGT400)
- Designs for larger aero CT’s (LM6000, SGT800) with equivalent heat rates to RICE developed and priced for comparison.
- Standalone combined cycle in this size range economically undesirable due to cost of turbine island. Marginal heat rate improvement over simple cycle CT’s and RICE.
- Repowering options considered. Eliminated due to siting considerations at Shiras and High $$/KW.
### Technical Comparison – RICE vs. Combustion Turbine (100 MW Site)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RICE</th>
<th>RICE</th>
<th>Aero CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom. Output Required (MW)</td>
<td>108</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Nom. Output / Unit (MW)</td>
<td>18</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>Units Required</td>
<td>6</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Appx. Heat Rate</td>
<td>8,400</td>
<td>8,400</td>
<td>8,650</td>
</tr>
<tr>
<td>Appx. Min. Output (MW)</td>
<td>6</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Appx. Start Time (min.)</td>
<td>3-5</td>
<td>3-5</td>
<td>10-15</td>
</tr>
<tr>
<td>Appx. Min. Gas Press (psig)</td>
<td>70</td>
<td>70</td>
<td>950</td>
</tr>
<tr>
<td>“Penalty” on Starts</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Sensitivity to Ambient Temp</td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>Sensitivity to Elevation</td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>Water Consumption</td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>Noise</td>
<td>HIGH</td>
<td>HIGH</td>
<td>MODERATE</td>
</tr>
</tbody>
</table>
Siting Considerations

Plant 4 Site Marginally in Floodplain
Coal Plant Site Presented Multiple Challenges that Create Cost Risk and Uncertainty

- Very Limited Real Estate
- Construction at Operating Plant Site Increases Demolition and Labor Costs
- O&M Problems with Fugitive Dust
- Cost to Address Concerns of Residents (Noise, Pollution, Construction Traffic)
- Harsh Lake Superior Conditions – Impacts Construction and Operations
- Tight Switchyard – Expansion Costs for Tie-in Quite High

Wright Street Site Near MBLP Offices Promising. Nearly a “Greenfield” Site.

Shiras Power Plant
Marquette, MI
U2: 20 MW  U3 44 MW
Siting Considerations

Wright Street Site Selected for Development

- Nearly a “Greenfield” Site
- Developed and Cleared, Level, with Limited Demolition Scope and Costs
- Close to Potential Natural Gas Supplies
- Good Space for Switchyard Tie-Ins
- Geotechnical Conditions Manageable
Extent of New Generation Considered
High Level Timeline

<table>
<thead>
<tr>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q1</td>
<td>Q1</td>
</tr>
<tr>
<td>Q2</td>
<td>Q2</td>
<td>Q2</td>
</tr>
<tr>
<td>Q3</td>
<td>Q3</td>
<td>Q3</td>
</tr>
<tr>
<td>Q4</td>
<td>Q4</td>
<td>Q4</td>
</tr>
</tbody>
</table>

- **Conceptual Study**
- Authorized
- **Study Complete**
- LNTP Engineering Release
- **Phase 4 Engineering Release**
- Wärtsilä LNTP Release
- **Receive Air Permit**
- Wärtsilä FNTP Release
- **Phase 5 Engineering Release**
- Receive Bonding
- Wärtsilä FNTP Release
- **FNTP Engineering Release**
- **Civil General Work Contract Award / Mobilization**
- **Units In Service**
- Machines Arrive at Port of Marquette
- **Mechanical / Electrical General Work Contract Award / Mobilization**
## Procurement Approach and Key Players

<table>
<thead>
<tr>
<th>Major Contracts</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICE Equipment</td>
<td>Wärtsilä</td>
</tr>
<tr>
<td>BOP Engineering and Construction Support</td>
<td>Sargent &amp; Lundy, LLC</td>
</tr>
<tr>
<td>Pre-Engineered Buildings</td>
<td>C.R. Meyer</td>
</tr>
<tr>
<td>Fuel Oil Storage Tank (Includes Erection)</td>
<td>Chattanooga Boiler and Tank</td>
</tr>
<tr>
<td>Generator Step Up Transformer</td>
<td>SPX Waukesha</td>
</tr>
<tr>
<td>Motor Control Centers</td>
<td>Eaton</td>
</tr>
<tr>
<td>Air Handling Units / HVAC Equipment</td>
<td>Trane</td>
</tr>
<tr>
<td>Pre-Engineered Pumphouse</td>
<td>Brownlee Morrow</td>
</tr>
<tr>
<td>Noise Study</td>
<td>Shiner and Associates</td>
</tr>
<tr>
<td>Natural Gas Gate Station Upgrades and Pipeline</td>
<td>Semco / Northern Natural Gas</td>
</tr>
<tr>
<td>Protective Relay Panels</td>
<td>Alstom C. Price EP2 Valmont</td>
</tr>
<tr>
<td>Civil General Work Contract</td>
<td>Miron</td>
</tr>
<tr>
<td>General Work Contract</td>
<td>Miron</td>
</tr>
</tbody>
</table>
Plant Layout Considerations

- **Existing Substation**
- **Steep Grade**
- **Neighborhood ~1,200 ft away**
- **Laydown Area ~4 acres**
- **Plant Site ~ 2 acres**
- **Plant Access Roads**
- **Neighborhood ~650 ft away**
- **Existing Buildings**
Plant Layout Considerations

- GSU Located Near Existing Switchyard
- Separate Electrical & Engine Hall Buildings
- Space for Future Unit
- Easy Truck Access
- Future Community Solar Garden
- Wide Aisle for Snow Removal
- Clear Path for Catalyst Replacement and Annual Emission Testing
- Tank Containment Optimized for Site
- Prefabricated Pump House

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WARTSILA 18V56DF ENGINES</td>
</tr>
<tr>
<td>2</td>
<td>SELECTIVE CATALYTIC REDUCER</td>
</tr>
<tr>
<td>3</td>
<td>EXHAUST STACK</td>
</tr>
<tr>
<td>4</td>
<td>FUEL OIL STORAGE TANK</td>
</tr>
<tr>
<td>5</td>
<td>PUMPHOUSE</td>
</tr>
<tr>
<td>6</td>
<td>OILY WATER SEPARATOR</td>
</tr>
<tr>
<td>7</td>
<td>RADITORS</td>
</tr>
<tr>
<td>8</td>
<td>GENERATOR STEP-UP TRANSFORMER</td>
</tr>
<tr>
<td>9</td>
<td>BLACK START GENERATOR</td>
</tr>
<tr>
<td>10</td>
<td>SWITCHGEAR ROOM</td>
</tr>
<tr>
<td>11</td>
<td>CONTROL ROOM</td>
</tr>
<tr>
<td>12</td>
<td>BATTERY ROOM</td>
</tr>
<tr>
<td>13</td>
<td>ELECTRICAL DDP ROOM</td>
</tr>
<tr>
<td>14</td>
<td>CHARGE AIR UNITS</td>
</tr>
<tr>
<td>15</td>
<td>AIR HANDLING UNITS</td>
</tr>
<tr>
<td>16</td>
<td>MBLP REGULATION AND METERING BLDG</td>
</tr>
<tr>
<td>17</td>
<td>UREA STORAGE TANK</td>
</tr>
<tr>
<td>18</td>
<td>SERVICE LUBE OIL STORAGE TANK</td>
</tr>
<tr>
<td>19</td>
<td>USED LUBE OIL STORAGE TANK</td>
</tr>
<tr>
<td>20</td>
<td>NEW LUBE OIL STORAGE TANK</td>
</tr>
<tr>
<td>21</td>
<td>UNLOADING PANELS</td>
</tr>
<tr>
<td>22</td>
<td>EMERGENCY EYE WASH / SHOWER</td>
</tr>
<tr>
<td>23</td>
<td>PIPE AND TRAY RACK</td>
</tr>
<tr>
<td>24</td>
<td>COMPRESSED AIR EQUIPMENT</td>
</tr>
<tr>
<td>25</td>
<td>MAINTENANCE WATER TANK</td>
</tr>
<tr>
<td>26</td>
<td>NATURAL GAS VALVE STATION</td>
</tr>
</tbody>
</table>
Noise Mitigation Considerations

Base Noise Mitigation

Considerations for Noise Study
- Nighttime and daytime ambient noise sampling
- No snow on ground
- No leaves on trees
- Local and state regulations

Noise Mitigation
- Sound attenuating insulation in engine hall
- Silencers on engine hall AHUs, ridge vent, & charge air intakes
- Low-noise radiators
- Radiator location farthest from receptors

Nearest Receptor Noise
- R3 @ 54 dBA
- R6 @ 49 dBA

R3 54 dBA

R6 49 dBA

R1 49 dBA 73 dBC
R2 52 dBA 74 dBC
R4 54 dBA 75 dBC
R5 52 dBA 75 dBC

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**Noise Mitigation Considerations**

**Optimized Noise Mitigation**

**Noise Mitigation**
- All of the base mitigation
- Added exhaust gas duct silencer at the outlet of each engine
- Replaced radiator fan blades with low noise blades
- Reduced radiator fan speed to reflect normal operating conditions

**Nearest Receptor Noise**
- R3 @ 49 dBA (-5 dBA)
- R6 @ 45 dBA (-4 dBA)

**Final Results**
- Target of 5-10 dBA over baseline values achieved
Engine Hall & Electrical Building Considerations

• Separate Engine Hall & EE / Control Bldg.
  ➢ Building form follows function
  ➢ EE / Control Bldg. size and design tailored to specific equipment
  ➢ Provides schedule and construction work plan flexibility – trades in separate areas
  Quieter control room

• Combined Bldg.
  ➢ Potential to reduce cost and commodities
  ➢ Consideration for firewalls and multiple HVAC zones required
  ➢ May be appropriate for space constrained sites - opportunity to integrate EE / Control Room / Maintenance Shop under one roof
Engine Hall & Electrical Building Considerations

Engineer Design vs. PreEngineered:

- **PE Bldg.**
  - Lower total cost
  - Potential for change orders
  - Turnkey solution

- **OE Bldg.**
  - Likely higher total cost (est. 10-25%) 
  - Increased schedule flexibility
  - Minimal risk for change orders
  - Readily customizable for unique applications or aesthetic reasons
Engine Hall HVAC Considerations

Air Handling Units (AHUs)

- **Significant Airflows, Size and Cost**
  - 100,000 cfm + per engine when in operation
  - 33% auxiliary side / 67% generator side airflows into building
  - Minimum airflow for hazardous classification when not running
  - Combustion air ducted separately from outside

- **Auxiliary Side Space Constraints – Factor AHU’s into Layout Early**

- **Cold / Hot Weather Installation**
  - Return & heating sections add significant size
  - Evaporative cooling may be needed for arid environments

- **Silencers May be Required (Noise Study)**
Project Costs Breakdown

Budget Cost ($65.1M)
(Prior to Detailed Engineering Authorization)

- Wartsila OEM Contract $31.4M
- Civil Labor Contract $5.3M
- Mech / Elec Labor Contract $16.7M
- Engineering, BOP Equipment, Buildings, & Other Costs $8.6M
- Contingency ($3.1M)

As-Delivered Cost (~$62.9M)

- Wartsila OEM Contract $31.9M
- Civil Labor Contract $6.4M
- Mech / Elec Labor Contract $17.3M
- Engineering, BOP Equipment, Buildings, & Misc. Other Costs $7.3M
- Contingency ($3.1M)
Keys to Success
Other Keys to Success

• Right Amount of Phase 1 Study Effort at the Right Time
• Fast Tracked Air Permit / Bonding Process
• Streamlined Performance Specifications
• Project Cost / Schedule Tracking
  ➢ Monthly Tracking of Actual Costs Vs. Estimate and Designed Commodities vs. Estimate
  ➢ Flexible Timing of Major Work Package Release Dates to Minimize Cost
  ➢ Close Management by Client of Wants vs. Needs
• RFI Responsiveness / Communication
Engine Hall Overview
Lower Galleries East of Engines
Radiators, Diesel Generator, GSUT
SCRs, Exhaust Stacks, Unloading Area