WÄRTSILÄ ENERGY SOLUTIONS
Electricity Supply Resource Technology Forum

Butte, MT
29 November 2017

Phil Rutkowski, Business Development Manager, Energy Solutions
WASHINGTON - 39 MW
Boulder Park (Avista) 32 MW
Olympic View (MCPUD3) 7 MW

OREGON - 236 MW
Port Westward 2 (PGE), 220 MW*
Wah Chang 16 MW

CALIFORNIA - 270 MW
Modesto (Mid) 50 MW
Humboldt (PG&E) 163 MW
Red Bluff (S&S) 57 MW

NEVADA - 118 MW
Barrick Gold Western 102 (BG)

COLORADO - 231 MW
Plains End I (EII) 113 MW
Plains End II (EII) 118 MW

NEBRASKA - 9 MW
Fall City 9 MW

NEW MEXICO - 47 MW
LCEC 47 MW

HAWAII - 32 MW
Kauai Utility 32 MW
HECO - 59 MW*

KANSAS - 145 MW
Midwest Energy 76 MW
Midwest Energy 28 MW
City of Iola 11 MW
Coffeyville 56 MW

TEXAS - 629 MW
Antelope (Golden Spread) 170 MW
Greenville (GEUS) 25 MW
Pearsall (STEC) 203 MW
Red Gate (STEC) 225 MW
Moss Bluff 8,000 Hp - 6 MW Compression
City of Denton 225 MW

OKLAHOMA - 56 MW
Stillwater - 56 MW

NORTH DAKOTA - 112 MW
Williston - 112 MW

MONTANA - 18 MW
Montana Dakota Utilities - 18 MW

ARIZONA - 188 MW
Tucson Electric Power - 188 MW*

MINNESOTA - 23 MW
Northern States Power, 14 MW
Hutchinson, 9 MW

MICHIGAN - 17 MW
Detroit Airport
Marquette, 51 MW
UMERG, 188 MW*

ILLINOIS - 25 MW
University of Illinois

INDIANA - 8 MW
City of Rensselaer

OHIO - 11 MW
Miami University, Oxford
Pennsylvania-32 MW
Borough of Chambersburg

NEW JERSEY - 9 MW
Mannington

MARYLAND - 31 MW
Sweetheart Cup 11 MW
BG&E 14 MW
Calvert Cliffs (BGE) 6 MW

MISSOURI - 12 MW
City of Kennett

TENNESSEE - 12 MW
El Paso 16,000 Hp Compression

ARKANSAS - 18 MW
City of Paragould

FLORIDA - 39 MW
Gainesville 7 MW
Tallahassee - 19 MW*

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+3,400 MW Total Capacity

● Power Plants greater than 100 MW

* Plants Under Construction
### Wärtsilä Engines

#### 20V34SG-D and 18V50SG-B

<table>
<thead>
<tr>
<th></th>
<th>20V34SG-D</th>
<th>18V50SG-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>9,370 kWe</td>
<td>18,817 kWe</td>
</tr>
<tr>
<td><strong>Heat Rate</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(LHV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(HHV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>720 rpm</td>
<td>514 rpm</td>
</tr>
<tr>
<td><strong>Dimensions</strong>&lt;sup&gt;•&lt;/sup&gt;</td>
<td>42’ x 11’ x 15’ 143 US tons</td>
<td>63’ x 18’ x 21’ 391 US tons</td>
</tr>
</tbody>
</table>

<sup>•</sup>At generator terminals (pf 0.8, 0% tolerance)

#### 20V34DF-B and 18V50DF

<table>
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<tr>
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<th>20V34DF-B</th>
<th>18V50DF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>9,340 kWe</td>
<td>17,076 kWe</td>
</tr>
<tr>
<td><strong>Heat Rate</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
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<sup>•</sup> At generator terminals (pf 0.8, 0% tolerance) when operating on natural gas with 1% liquid pilot fuel.
**Start Times**
- 2 min (hot start), 5 min (warm start) – 34SG
- 5 min (hot), 10 min (warm) – 50SG
- Ideal for cycling operation
- No maintenance impact (maintenance is strictly hours based)

**Min Up time** = 1 min or less

**Min Down time** = 5 min (gas purge cycle)

**Cycling** has no impact on O&M

**Ramping:** Note there are TWO RAMPING REGIMES
- **Start Ramp** is 20% to 50% per minute (for 5 and 2 min start)
- **Operational Ramp** is 30% to 100% load in 40s (equates to 105%/min)
- Equivalent to many hydro facilities
Natural Gas (“NG”) Thermal Resources

:Servant or Master?
Generation by Fuel Source

https://www.eia.gov/electricity/annual/html/epa_03_01_a.html
Like most Thermal Resources, fuel costs drives electricity costs
This plays into the Merit Order dispatch model of resources
What happened that made NG Resources such a dominant player?

Fracking & economics, not environmental policies have pushed NG
### “TYPICAL” GAS POWER PLANT ALTERNATIVES

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Gas Turbine - Industrial</th>
<th>Gas Turbine – Aero derivate</th>
<th>RICE</th>
<th>Combined Cycle Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 X 7FA</td>
<td>1 X LM6000PG - Sprint</td>
<td>12 X 18V50SG</td>
<td>1 - 1</td>
</tr>
<tr>
<td>Heat rate HHV (ISO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output MW (ISO)</td>
<td>205.0</td>
<td>48.7</td>
<td>226.5</td>
<td>308.0</td>
</tr>
<tr>
<td>Output MW (5000 fasl)</td>
<td>166.4</td>
<td>37.3</td>
<td>226.5</td>
<td>251.4</td>
</tr>
<tr>
<td>Output MW (5000 fasl &amp; 77F)</td>
<td>161.1</td>
<td>35.1</td>
<td>226.5</td>
<td>244.0</td>
</tr>
<tr>
<td>Investment cost (ISO)</td>
<td>700 $/kW</td>
<td>1,200 $/kW</td>
<td>900 $/kW</td>
<td>1,000 $/kW</td>
</tr>
<tr>
<td>Minimum stable load</td>
<td>25 %</td>
<td>25 %</td>
<td>10 % (per engine)</td>
<td>25%</td>
</tr>
<tr>
<td>Variable O&amp;M cost</td>
<td>1 $/MWh</td>
<td>3.5 $/MWh</td>
<td>6 $/MWh</td>
<td>5 $/MWh</td>
</tr>
<tr>
<td>Start-up cost</td>
<td>10,000 $/start</td>
<td>0</td>
<td>0</td>
<td>15,000 $/start</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>15 $/kW</td>
<td>20 $/kW</td>
<td>15 $/kW</td>
<td>30 $/kW</td>
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**Engineer’s Dream:**
The King of Efficiency!
Annual installed power generation capacity in the U.S.

- Renewables
- Hydro
- Nuclear
- Oil
- Gas
- Coal

GW


BUT THAT’S NOT WHERE THE STORY ENDS...
MARKET VOLATILITY WILL INCREASE

Renewables

- Will depress wholesale market prices and change the price duration curve
- More very low and very high priced periods

New Market Rules

- "How to cope with the duck curve?"
- FERC ruling 825 will impact all ISO markets
- Beyond the new ramping product discussion

Volatility as an Opportunity

- Increasing price volatility is seen as a risk if you don’t have tools to cope with it
- Volatility is an opportunity for a portfolio with flexible assets
Once again, this plays into the Merit Order dispatch model of resources. RE is taken first and depresses prices but unfortunately is also intermittent.
As renewable resources increase in the generation portfolio, the “net demand” increases in volatility.
Tucson Electric Power – ten minute ramping changes

Historical Load Volatility
Chart 2 - 10-Minute Changes in TEP Retail Demand in 2016

Future Renewable Intermittency
Chart 4 - 10-Minute Changes in TEP Renewable Energy Generation (2024 Forecast)
SO WHAT RESOURCES ARE BEST TO MEET THIS INTERMITTENCY?

Loading sequence of thermal power plants

- Coal Fired power plant
- Combined Cycle power plant (GTCC)
- Aeroderivative GT power plant (GTSC)
- Industrial GT power plant (GTSC)

Note: Start up times from hot stand-by!

© Wärtsilä
Unloading sequences for power plants

- **Combined Cycle power plant (GTCC)**
- **Industrial GT power plant (GTSC)**
- **Combustion Engine power plant**
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<td>1 X LM6000PG - Sprint</td>
<td>12 X 18V50SG</td>
<td>1 – 1</td>
</tr>
<tr>
<td>Start time to Full Power</td>
<td>11 minutes*</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>45 minutes</td>
</tr>
<tr>
<td>Minimum Up Time</td>
<td>4 hours</td>
<td>5 minutes</td>
<td>&lt;1 minute</td>
<td>4 – 12 hours</td>
</tr>
<tr>
<td>Shut down</td>
<td>15 minutes</td>
<td>Few minutes</td>
<td>&lt;1 minute</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Start costs</td>
<td>$10,000/start</td>
<td>0*</td>
<td>0</td>
<td>$15,000/start</td>
</tr>
<tr>
<td>Minimum stable load</td>
<td>25%</td>
<td>25%</td>
<td>10% (per engine)</td>
<td>25%*</td>
</tr>
<tr>
<td>Minimum stable load (ISO)</td>
<td>52MW</td>
<td>12MW</td>
<td>2MW</td>
<td>77MW*</td>
</tr>
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Utility Scale RICE: The King of Flexibility!
HOW DOES FLEXIBILITY MATTER WHEN ANALYZING PORTFOLIOS

Example from a real IRP in the Rocky Mountains Dispatch – Base CASE 2035 – Low demand week

Every time a Combined Cycle or HD CT starts/stops, it’s a minimum of $10,000
In the image, there is a graph labeled "Same week Dispatch – High res 2035 – Low demand week." The graph shows various energy sources over a period from 2007 to 2017, with categories such as Nuclear, Combined Cycle, New build Wärtsilä, Open Cycle, Gas Turbines, Wind, and Solar. The graph indicates that Combined Cycles are still cycling, but overall, there are fewer Gas Turbines with start costs employed. Wärtsilä has a $0 start cost, and fast ramps allow for more renewable energy (RE).
### Net present value of required future revenues

<table>
<thead>
<tr>
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<th>Base Case</th>
<th>100 % of New Gas RICE</th>
<th>High RES – 100 % RICE</th>
</tr>
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<tbody>
<tr>
<td>Net Present value of required revenues – 3% Load following</td>
<td>$5,553,389,360</td>
<td>$5,470,753,016</td>
<td></td>
</tr>
<tr>
<td>Difference to the Base case</td>
<td></td>
<td>($82,636,343)</td>
<td></td>
</tr>
<tr>
<td>Net Present value of required revenues – 7% Load following</td>
<td>$5,619,712,486</td>
<td>$5,502,211,222</td>
<td>$5,297,364,073</td>
</tr>
<tr>
<td>Difference to the Base case</td>
<td></td>
<td>($117,501,263)</td>
<td>($322,348,413)</td>
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*NPV (5.2%, 20 yrs, (VOM + FOM + CAPEX))

Wärtsilä found that this IOU achieved the greatest cost savings by building MORE Renewable Energy with LESS thermal resources IF they employed HIGHLY FLEXIBLE Wärtsilä technology.
Wärtsilä flexibility helps City of Denton achieve 70% renewable energy base by 2019 while the ratepayers will save ~$975M over 20 years over the current portfolio.

Denton’s energy mix 2016:
- Market purchase: 30%
- Renewable PPA: 40%
- Coal ownership: 29%

Denton’s energy mix 2019:
- Renewables: 70%
- Flexible gas generation: 13%
- Market purchase: 17%
Heorot Power to Sell or Close Montana Coal Station

Nov 20, 2017

By Editors of Power Engineering

A coal-fired facility that is just 11 years old already faces closure, according to a filing with state regulators.

Gary Arneson, vice president of operations for Heorot Power, told the Montana Public Service Commission that if the company can't sell the 116-MW Harlin Generating Station, it could close by the second quarter of 2018, the Billings Gazette reported.

"Unfortunately, these losses are no longer sustainable, and the Company is forced to make a decision about the plant's future," he said.

The plant, which has relied on short-term power purchase contracts, purchases 550,000 tons of coal annually from the Absaloka mine on the nearby Crow Indian Reservation.

Heorot Power has defaulted on payment on $12 million in bonds to build infrastructure supporting the plant, and has not paid 2016 taxes. The company is actively seeking a buyer for the plant.
But efficiency still matters, right?

Top Plant: Irsching 4 Combined Cycle Power Plant, Irsching, Bavaria, Germany

Owner/operator: E.ON

The Irsching 4 Combined Cycle Power Plant has set a new world record in power plant efficiency with its new SGT5-8000H gas turbine. With an output of more than 578 MW and efficiency of 60.75% (net) achieved at a world record test run in May 2011, the plant demonstrates that climate protection, low-cost power generation, and flexible operation using fossil fuels can be attained simultaneously through technical advances. Due to its high efficiency, the gas-fired plant uses significantly less fuel and produces lower carbon dioxide emissions than traditional combined cycle plants.

Owners to shut down German gas-fired power plants

An ownership consortium consisting of E.On, HSE, Mainova, and N-ERGIE has notified the German Federal Network Agency and network operator TenneT of its plans to shut down Irsching 5, a high-efficiency combined-cycle gas turbine.

Their plan is to take Irsching 5 offline effective April 1, 2016. E.On, the sole owner of Irsching 4, likewise notified the Federal Network Agency of its plan to shut down this power plant effective the same date.

The decisions were made because the two gas plants have no prospect of operating profitably when the current contract with the network operator expires in March 2016.
But efficiency still matters, right?

Panda Temple I plant files for Chapter 11 bankruptcy
BY CODY WEEMS | TELEGRAM STAFF May 11, 2017

Exelon Generation Texas Power Files Chapter 11 Bankruptcy
Nov 7, 2017

California gas power plant La Paloma files for bankruptcy
Reuters Staff
CHICAGO (Reuters) - A natural gas-fired power plant in California that earlier this year warned it might need to shut down filed for bankruptcy protection on Tuesday, blaming “inhospitable” regulations and a shift toward renewable energy for power generation.

A group of investors is buying debt-ridden Calpine for $5.6 billion
John Benny, Reuters
© Aug. 18, 2017, 8:10 AM 6 1,771
Renewables are the new base energy

- Not just a green image anymore
- More and more affordable PPA contracts available
- Economical option compared to gas baseload

Volatile market is your friend

- Generation volatility will increase
- Flexible capacity provides an ability to hedge AND extract value from the market

Gas as integrator, not new baseload

- No room for gas baseload – renewables are more economical option and less risky
- Flexible gas capacity as enabler
Please enjoy my colleague’s book on the transformation happening to U.S. utilities

https://www.smartpowergeneration.com/content-center/books/goodbye-to-deerland