# Market and Technology Assessments of Crosscutting Research

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NETL Office of Program Performance and Benefits

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U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

# What does the Benefits Division Do?

- **Forecast Benefits**
  - Quantify the economic and environmental impacts of system deployments
  - Compare advanced technology deployment benefits across various policy and economic scenarios
  - Review third-party economic and environmental technology impact assessments

- **Provide Program Guidance**
  - Determine industry needs and alignment with R&D program
  - Assess opportunities in various market niches and market size
  - Examine cost and performance necessary for technologies to deploy

- **Develop Modeling Capability**
  - Design and test methodologies for quantifying benefits and understanding investment decision making
  - Promote the integration of new technologies into external models

# Crosscutting Analysis Projects

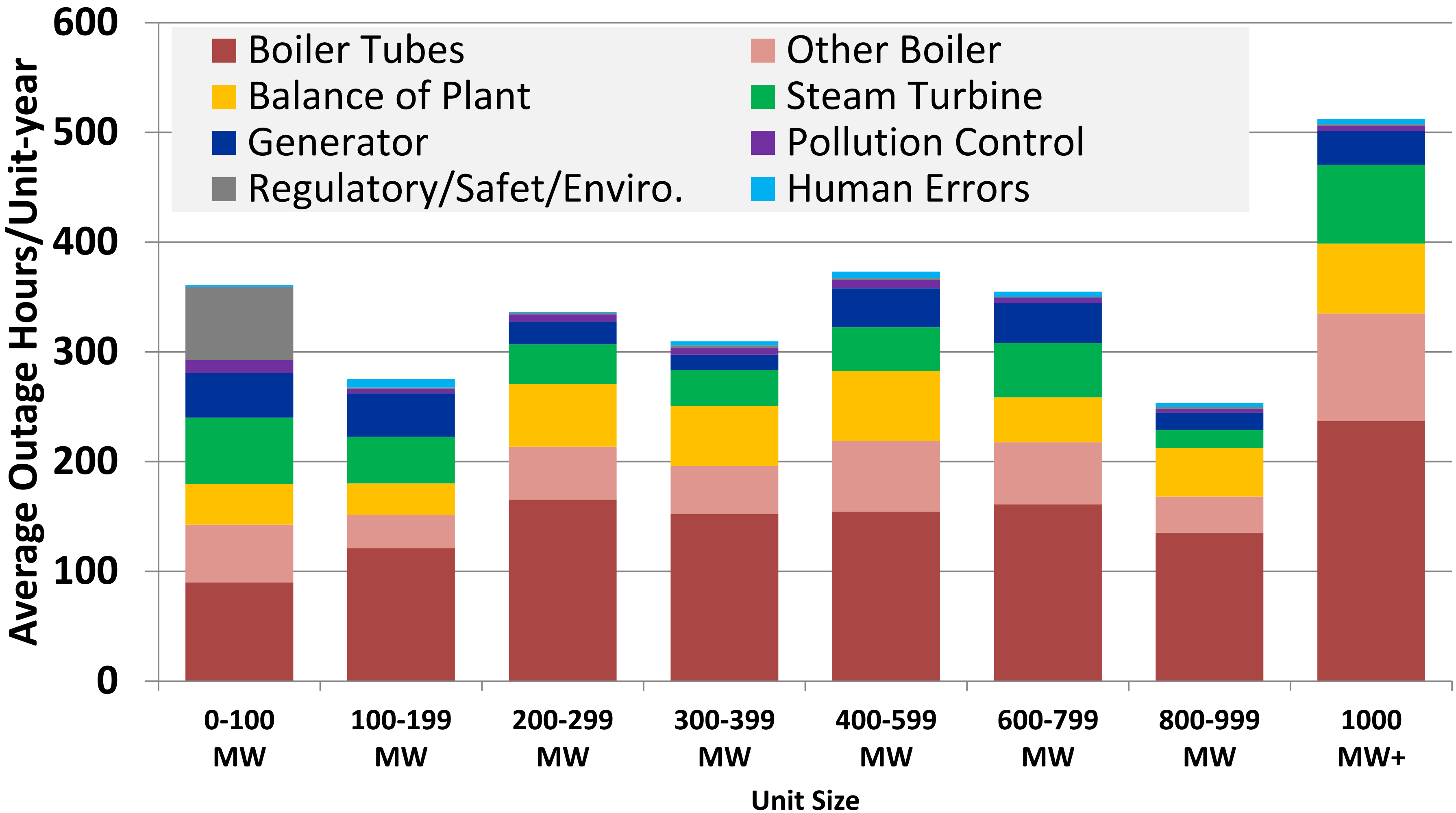
- **Economic Opportunity for the Existing Coal Fleet to Refurbish with Advanced Sensors and Controls**
  - **http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Potential-Impact-of-Improved-Sensors-Controls.pdf**
  - **http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Benefits-of-Advanced-Sensors-and-Controls.pdf**
- **Economic Opportunity for Advanced Material Boiler Tubes – Draft Report Complete**
- **Assessment of Sensors, Controls and Advanced Materials in Load Following Coal Units– Summer 2014**
- **Global Advanced Materials Market Assessment – Summer 2014**
  - **Market Outside of Coal Power Sector**
  - **International – AUSC**
- **Computational Modeling Benefits– Summer 2014**

# Economic Opportunity for the Existing Coal Fleet to Refurbish with Advanced Sensors and Controls

## Steps in Conducting Assessment

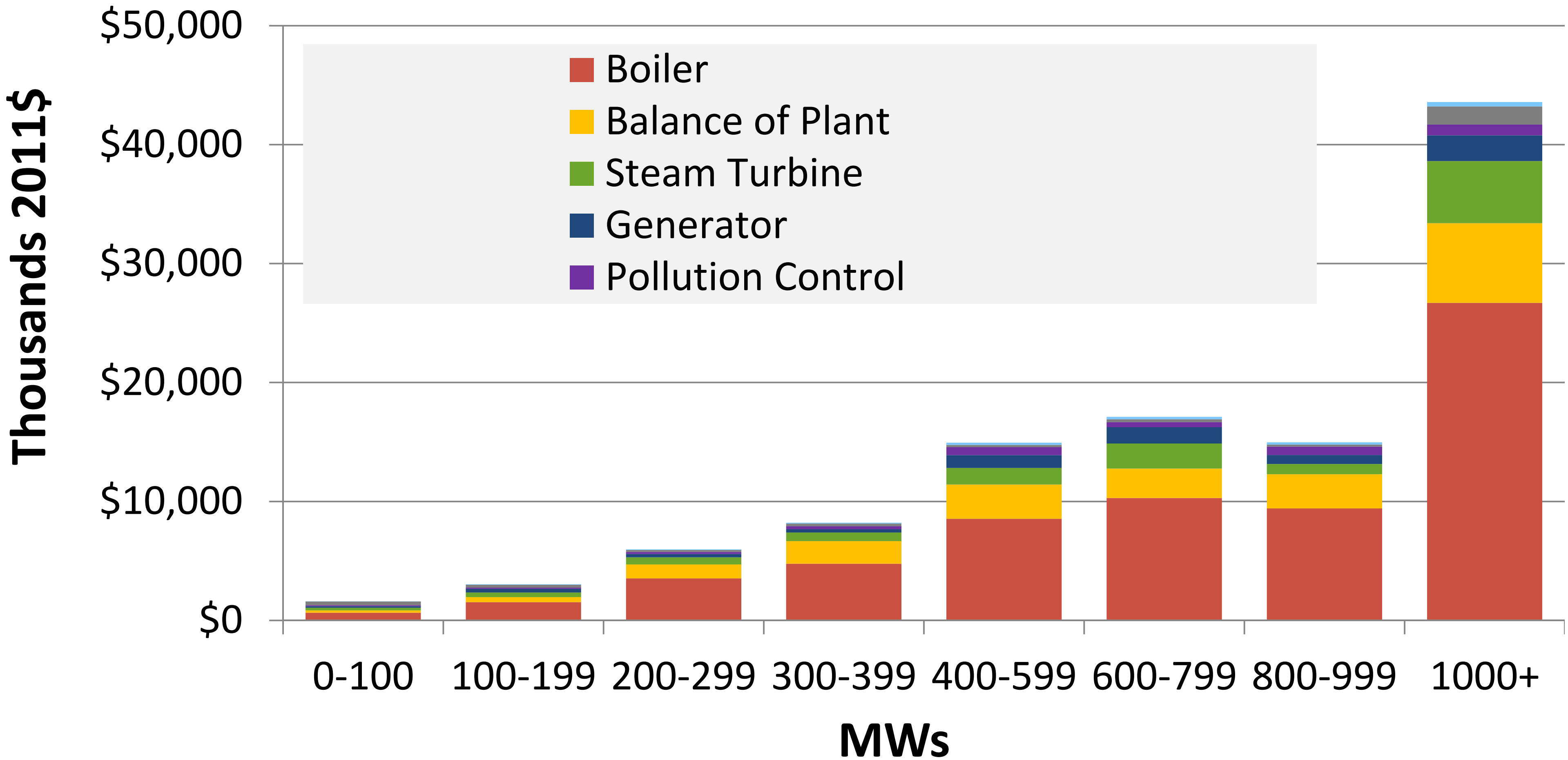
1. **Research & data gathering to determine inputs ranges.**
    - Literature searches for past projects
    - Vendor data
    - Worley Parson's expert opinion
2. **Use a flexible tool to assess input sensitivities**
    - Excel based discounted cash flow analysis
    - Unit level Ventyx data – unit size, CF, heat rate, fuel costs, etc.
    - Internal rate of return, payback period
3. **Analyze in National Energy Modeling System (NEMS) to determine long term benefits to society and program return on investment**

# 2007-2011 Average Annual Plant Lost Production Time Due to Forced Outages in Coal Units




*Source: Outage Data - NERC GADS Database 9/19/12 Accessed 1/29/13; Avg. Wholesale Price Data – EIA http://www.eia.doe.gov/cneaf/electricity/wholesale/wholesale.html Wholesale Market Data, PJM West, Indiana, ERCOT, Mid-Columbia 2011 Wtg. Avg. of $46.28/MWh*

# 2007-2011 Average Annual Revenue Loss Due to Equipment Forced Outages and Derates in Coal Units

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http://www.eia.doe.gov/cneaf/electricity/wholesale/wholesale.html Wholesale Market Data, PJM West, NEPOOL, ERCOT Wtg. Avg;

# Coal Unit Cost and Performance of Previous Sensors and Controls Projects

| MWs | Capital Cost (Thousand $) | O&M Cost (Thousand $/yr) | Reduction in Operator Cost (Thousand $/yr/unit) | Reduction in HR (Btu/KWh) | Nox Reduction (%) | Availability Improvements: Increased Operation Hours (Hr/Yr) | Availability Improvements: Net Generation Increase (MWh) | Availability Improvements: Contract Maint. Savings (Thousand $/Yr) |
|---|---|---|---|---|---|---|---|---|
| 0-99 | $500 - $600 | $50 - $60 | $120 | 175 - 225 | 5 - 8 | 91 | 5,400 | $540 |
| 100-199 | $500 - $600 | $50 - $60 | $120 | 175 - 225 | 5 - 8 | 54 | 7,300 | $320 |
| 200-299 | $600 - $700 | $60 - $70 | $120 | 125 - 175 | 5 - 8 | 65 | 14,900 | $390 |
| 300-399 | $600 - $700 | $60 - $70 | $120 | 125 - 175 | 5 - 8 | 44 | 14,300 | $260 |
| 400-599 | $800 - $900 | $70 - $80 | $120 | 75 - 125 | 5 - 8 | 74 | 38,000 | $440 |
| 600-799 | $800 - $900 | $70 - $80 | $120 | 75 - 125 | 5 - 8 | 60 | 39,500 | $360 |
| 800-999 | $900- $1,000 | $80 - $90 | $120 | 25 - 75 | 5 - 8 | 43 | 36,300 | $255 |
| 1000+ | $900 - $1,000 | $80 - $90 | $120 | 25 - 75 | 5 - 8 | 73 | 90,300 | $435 |

*Source: Worley Parsons opinion after review of past projects involving sensors and controls. Draft Paper Potential Impact of Improved Sensors & Controls and Advanced Materials on Coal-Fired and NGCC Power Plant Operations*

# Business Case Tool - Net Present Value Analysis (NPV)

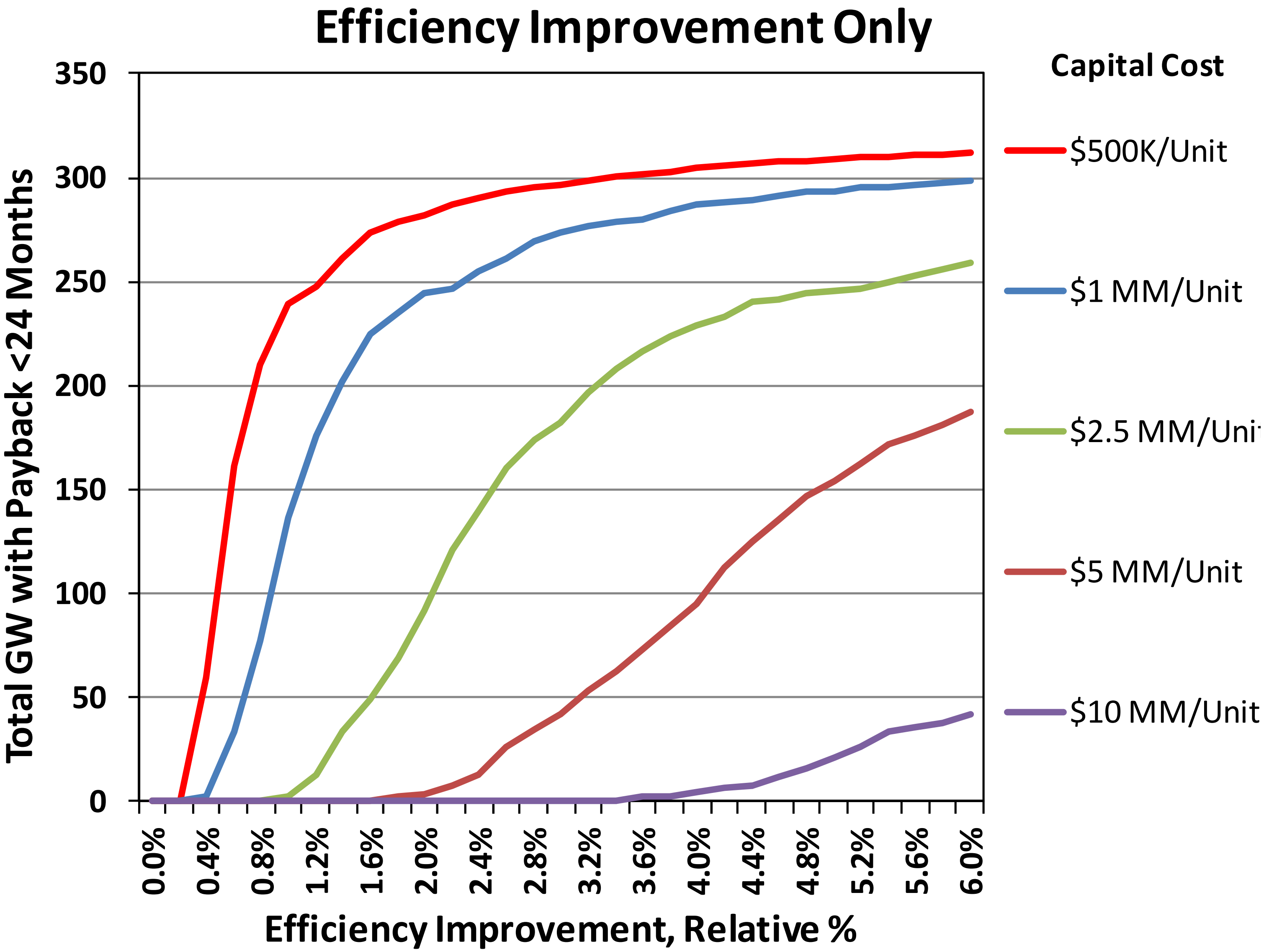
- Previous table established input ranges to determine which plants would benefit economically from a Sensors and Controls refurbishment project.

- Obtained Unit level data from the Energy Velocity database
  - Electric price
  - Fuel price
  - Current heat rate
  - Emissions
  - Capacity Factor

- Built an NPV tool to model the business case decision of each unit

- Assumed units would only refurbish if they could payback in 2 years

# Coal Unit NPV Analysis

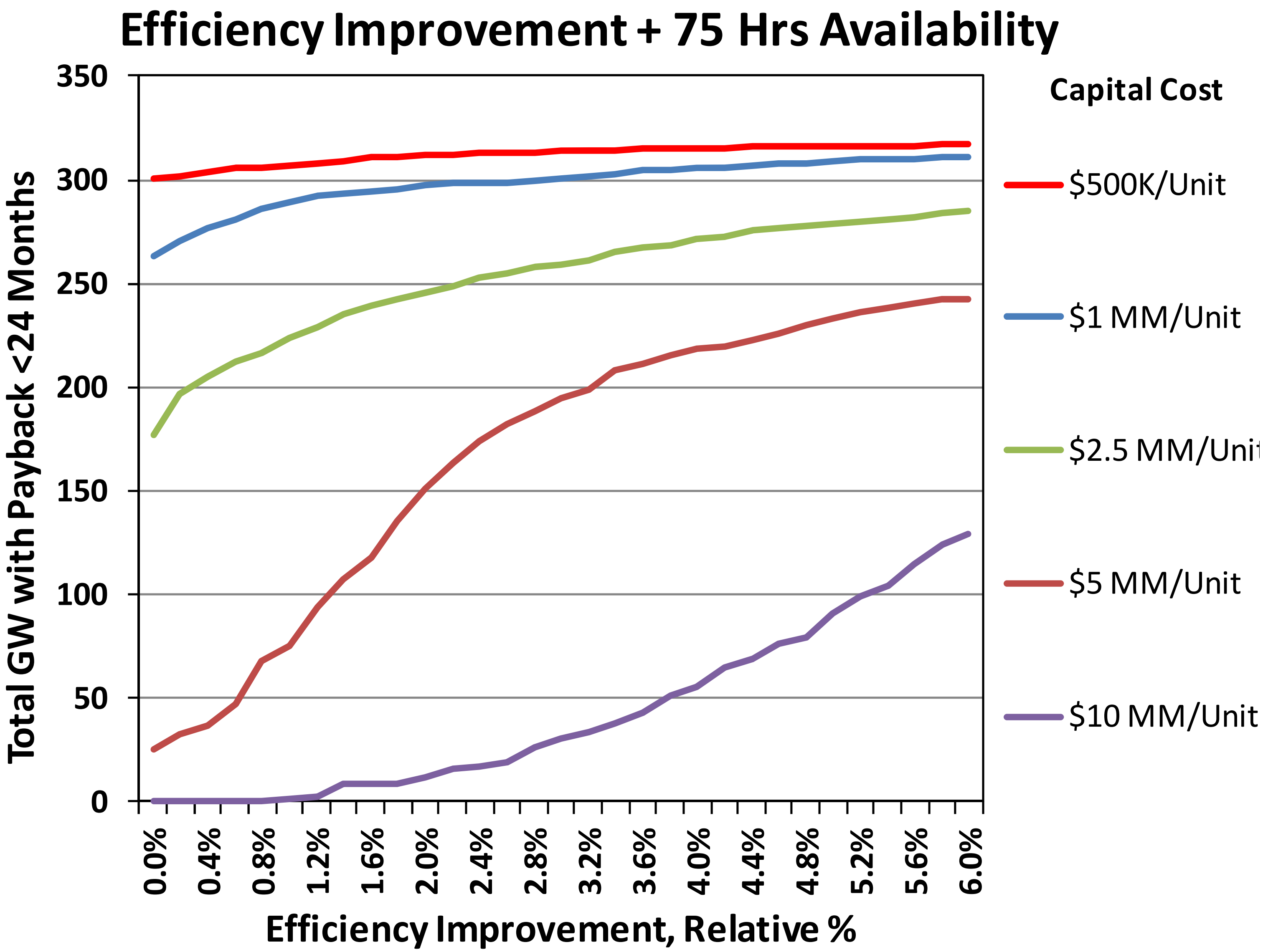



*Source: Results based on unit by unit discounted cash flow model. Unit level data taken from 2010 Ventyx database. Cost and performance based on NETL survey of previous sensors and controls projects.*



NETL

# Coal Unit NPV Analysis






*Source: Results based on unit by unit discounted cash flow model. Unit level data taken from 2010 Ventyx database. Cost and performance based on NETL survey of previous sensors and controls projects.*

# Summary of NEMS Run Results AEO2013 Year 2040

| | Refurbish Capacity (GW) | | Generation (BkWh) | | Average US COE (¢/kWh) | Total Electric Sales (BkWh) | US Total Electric Bill (Billions 2011$) |
|---|---|---|---|---|---|---|---|
| | Coal (out of 272) | NGCC (out of 219) | Coal | NGCC | | | |
| AEO2013 Reference | 0 | 0 | 1807 | 1298 | 10.02 | 4432 | 495.4 |
| Low Cost/Low Performance | 263 | 108 | 1810 | 1291 | 9.98 | 4435 | 495.1 |
| High Cost/High Performance | 246 | 109 | 1821 | 1277 | 9.97 | 4437 | 495.3 |

- **Program benefits from reductions in cost of electricity** (assuming plant optimization program continues to be funded at current levels)
  - Total Electric bill savings (year 2013 to 2040) $8-$10 billion
  - Cost of $CO_2$ avoided $2-$10/mt

# Crosscutting Analysis Projects

- Economic Opportunity for the Existing Coal Fleet to Refurbish with Advanced Sensors and Controls
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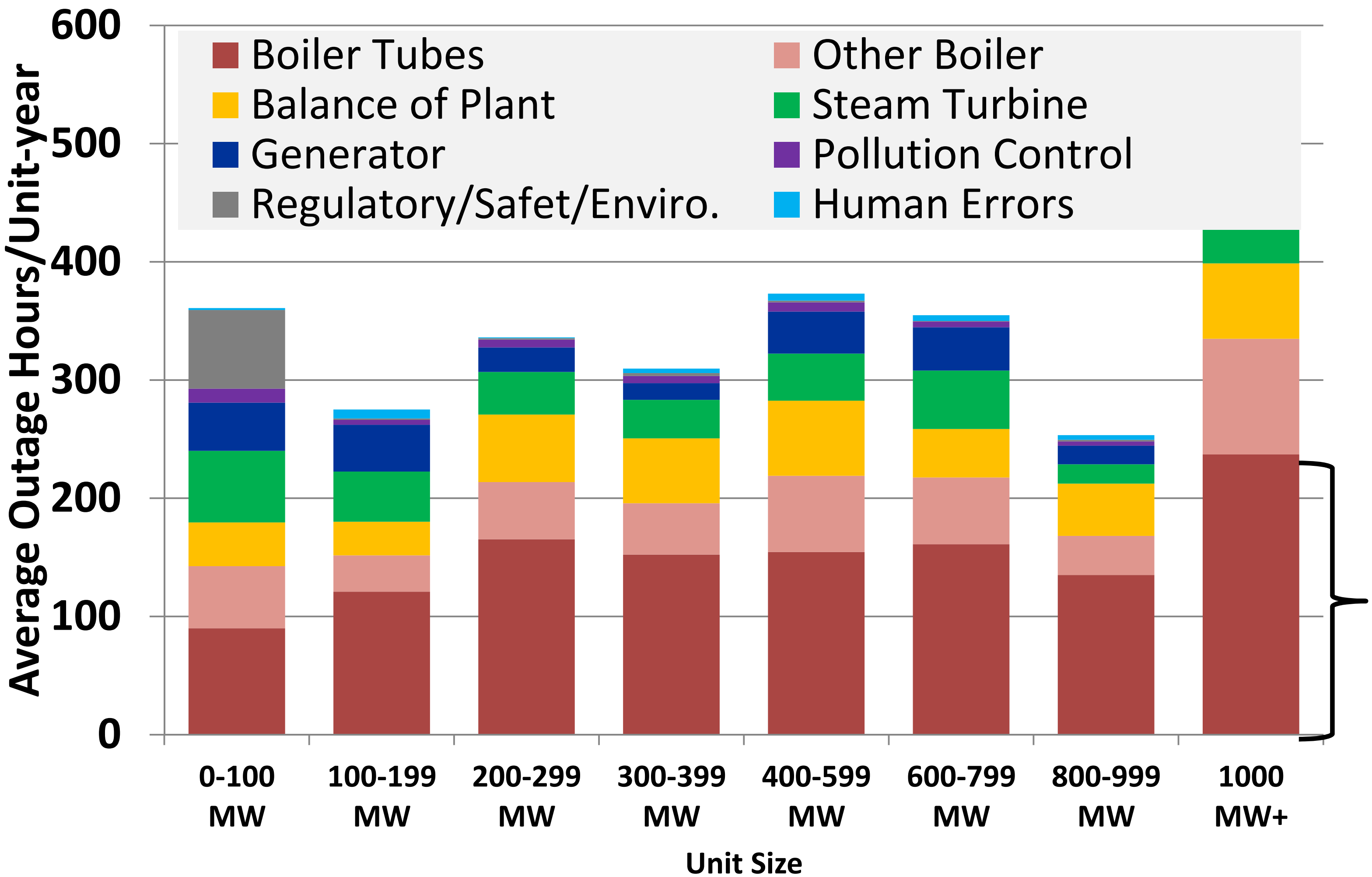
# Boiler tube failures account for $3-$15 million in lost revenues for 300MW – 1GW+ Coal Units




In 1GW+ Coal Units, 46% of forced outage revenue losses were due to boiler tubes

*Source: Outage Data - NERC GADS Database 9/19/12 Accessed 1/29/13; Avg. Wholesale Price Data – EIA* *http://www.eia.doe.gov/cneaf/electricity/wholesale/wholesale.html Wholesale Market Data, PJM West, Indiana, ERCOT, Mid-Columbia 2011 Wtg. Avg. of $46.28/MWh*

# EUCG - Plant Availability Reduction Due to Boiler Tube Failures

| Failure Category | Occurrence (failures/year) | Lost Unit Operation Hours (hours/year) | Unit Average Net Generation Decrease (MWh/year) |
|---|---|---|---|
| **Stress-Rupture** | 0.15 | 38 | 23,100 |
| **Water-side Corrosion** | 0.08 | 22 | 13,000 |
| **Fire-side Corrosion** | 0.32 | 84 | 50,400 |
| **Erosion** | 0.15 | 40 | 24,100 |
| **Fatigue** | 0.11 | 30 | 18,000 |
| **Lack of Quality Control** | 0.09 | 23 | 14,100 |
| **TOTAL** | **0.90** | **238** | **143,000** |

 *Source: DOE/NETL, 2005 EUCG Survey*

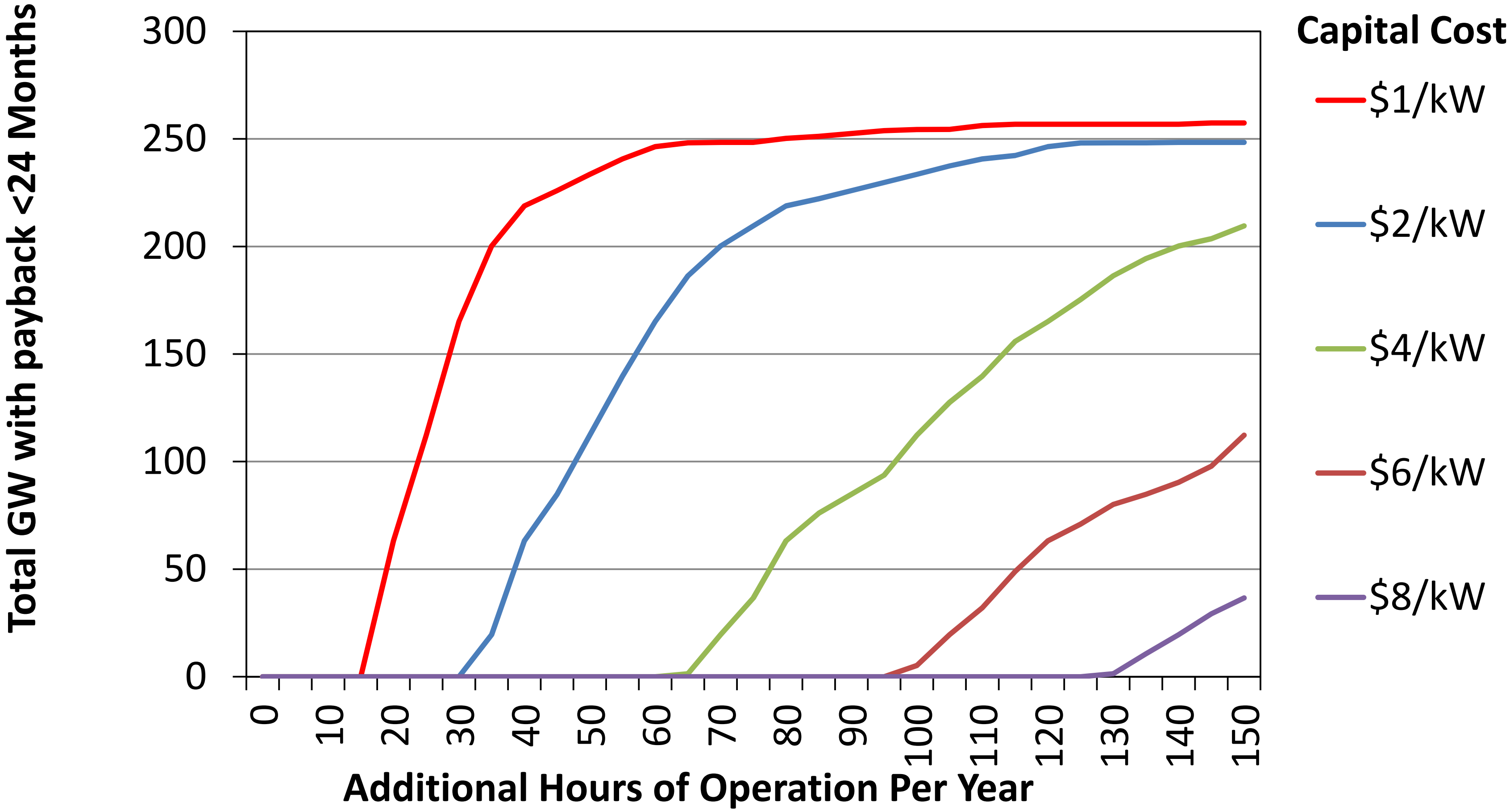
# NETL Application of Advanced Technologies

| Project Number | Material Description | Characteristics Beneficial to Boiler Tubes | Boiler Tube Benefits |
|---|---|---|---|
| **FWP AL-07-360-019** | Novel High-Temperature Alloy (NiAl-10Mo) | High temperature corrosion resistance | Reduction in fireside corrosion |
| **FE0005869** | Creep-Resistant Iron-based (Ferritic) Superalloy (FBB8 Alloy) | High creep resistance | Reduction in stress rupture and fatigue |
| **Adv Comb – Task 4.3.1** | Advanced 9Cr Creep-Resistant Steel (CSEF Alloy) | High creep resistance | Reduction in stress rupture and fatigue |
| **FWP-1168** | High-Temperature Erosion-Corrosion Resistant Fe3Al Metal Coating (Fe3Al Coating) | Lower erosion-corrosion loss rates | Reduction in erosion, fire-side corrosion, and fatigue |
| **FWP-12461** | Friction Stir Welding Process (FSW) | High creep resistance, oxidation and sulfidation resistance | Reduction in fire-side and water-side corrosion |

# Partial Tube Replacement Concept

- **Capital cost to use advanced material to replace all of the boiler tubes would be cost prohibitive.**
- **However, if only a critical section of tubes (say 10% of superheater or reheater) is replaced with advanced materials, the capital cost is much lower.**
- **Suppose advanced materials are used in the most problematic boiler area, resulting in 33%-50% less forced outages.**
- **The cost of advanced materials in this scenario could be justified.**

# Capital Cost Effect of Advanced Materials for Boiler Tube Replacement in Coal Units Built Before 1990



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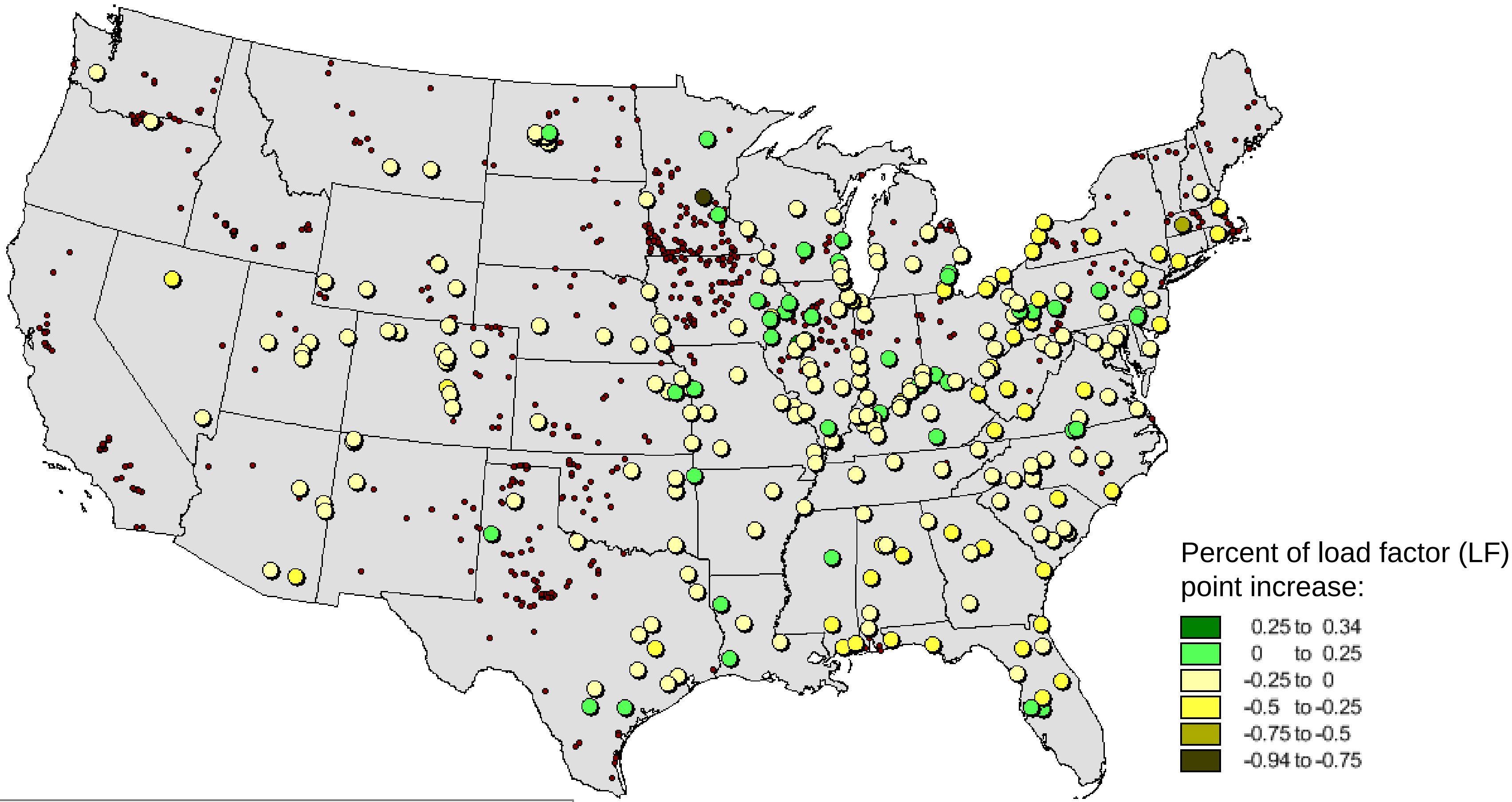
# Load Following - Study Overview

**Objective:** Evaluate economic opportunities for advanced sensors, controls, and materials in existing coal units that are load following

**Steps**

1. Determine the GWs of existing coal units that are load following in the U.S. and understand the causes of load following: renewables, economy, low NG prices
2. Identify the key problem areas that a load following coal unit may face. Determine how advanced sensors, controls and materials may alleviate load following issues.
3. Use a forecasting tool such as NEMS to determine how load following may change in the future under the scenarios identified by the regression analysis as being a root cause. Qualitatively describe the potential benefits of advanced sensors, controls and materials in load following units now and in the future.

# 75 percent of the subcritical coal fired units that operated in 2002 have seen load factor decrease in the last 10 years




Presently, out of 904 units that operated in 2002:

- 58 units (7.6 GW) have the same LF as in 2002
- 682 units (239.7 GW) have lower LF than in 2002
- 164 units (64 GW) have higher LF than in 2002

58 GW of wind generating units were added since 2002.



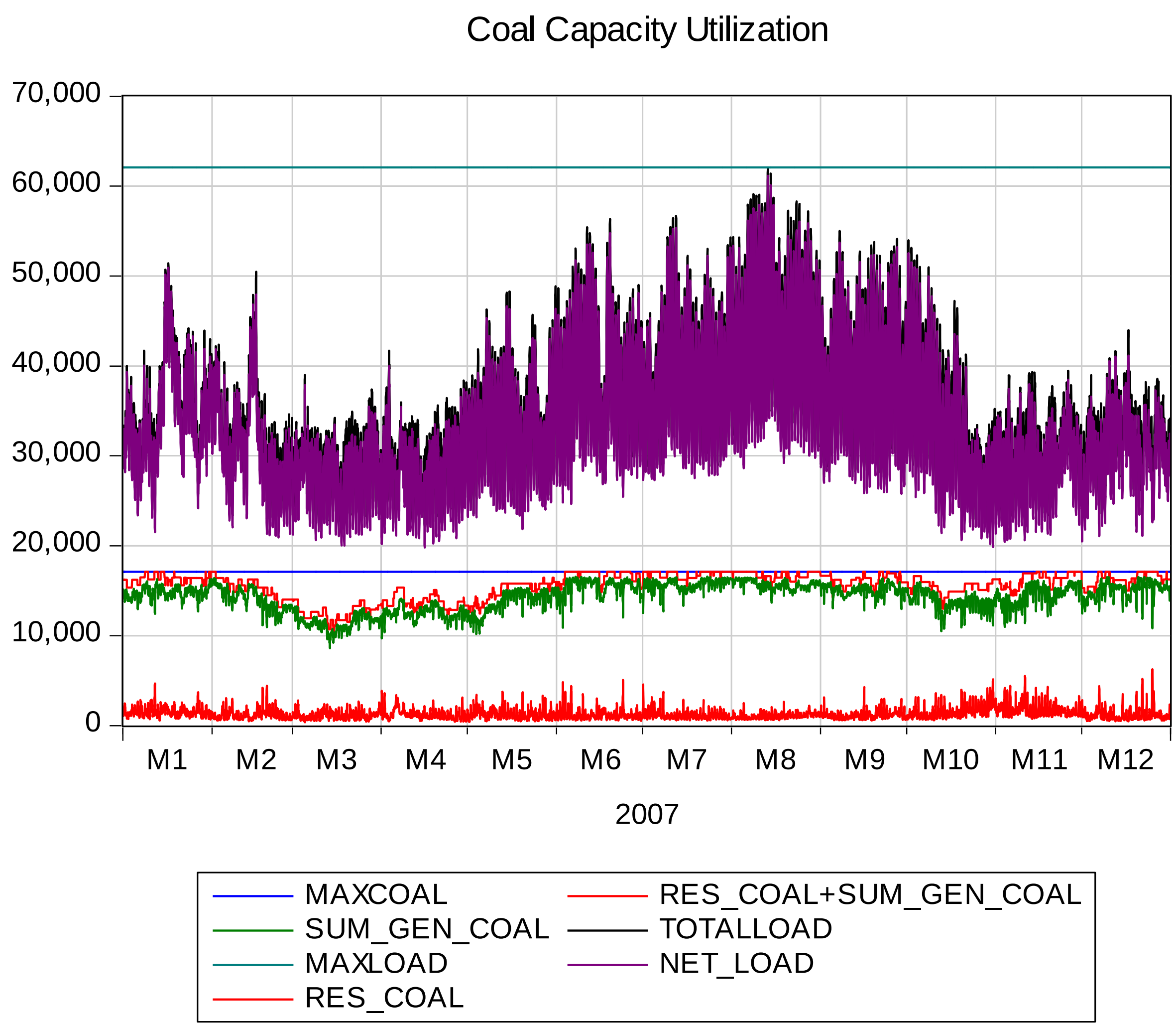
*Data source: Velocity suite*

# ERCOT - 2007 Market Overview

- ✓ Aggregate coal capacity was 17,100 Mw
- ✓ Average coal capacity factor was 84 %
- ✓ Average coal spinning reserve was 1,286 Mw

- ✓ Peak Load was 62,101 Mw
- ✓ System load factor of 56 %

- ✓ Average wind and other supply was 1,460 Mw
- ✓ Max Wind Output was 3,407 Mw

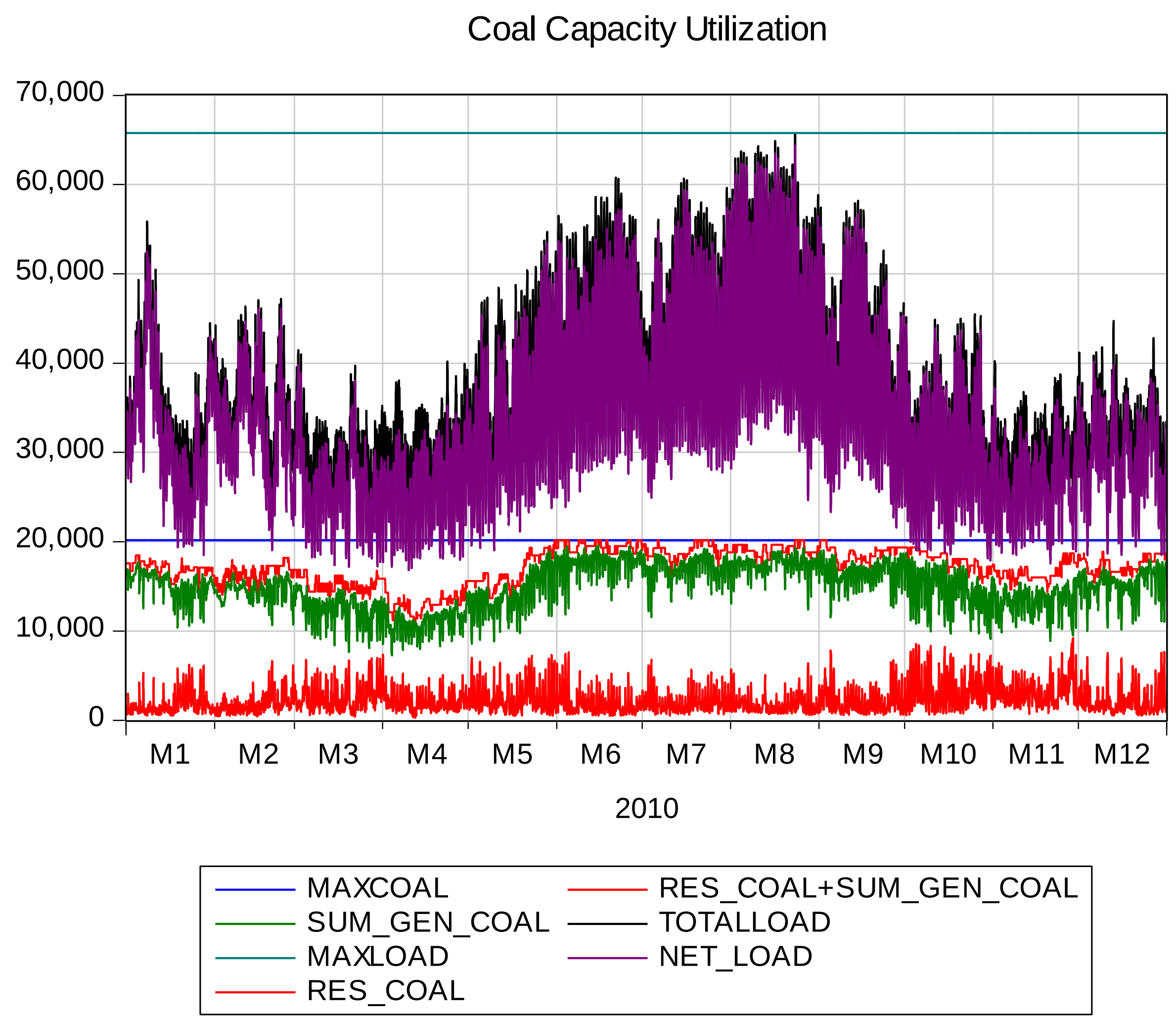


# ERCOT - 2010 Market Overview

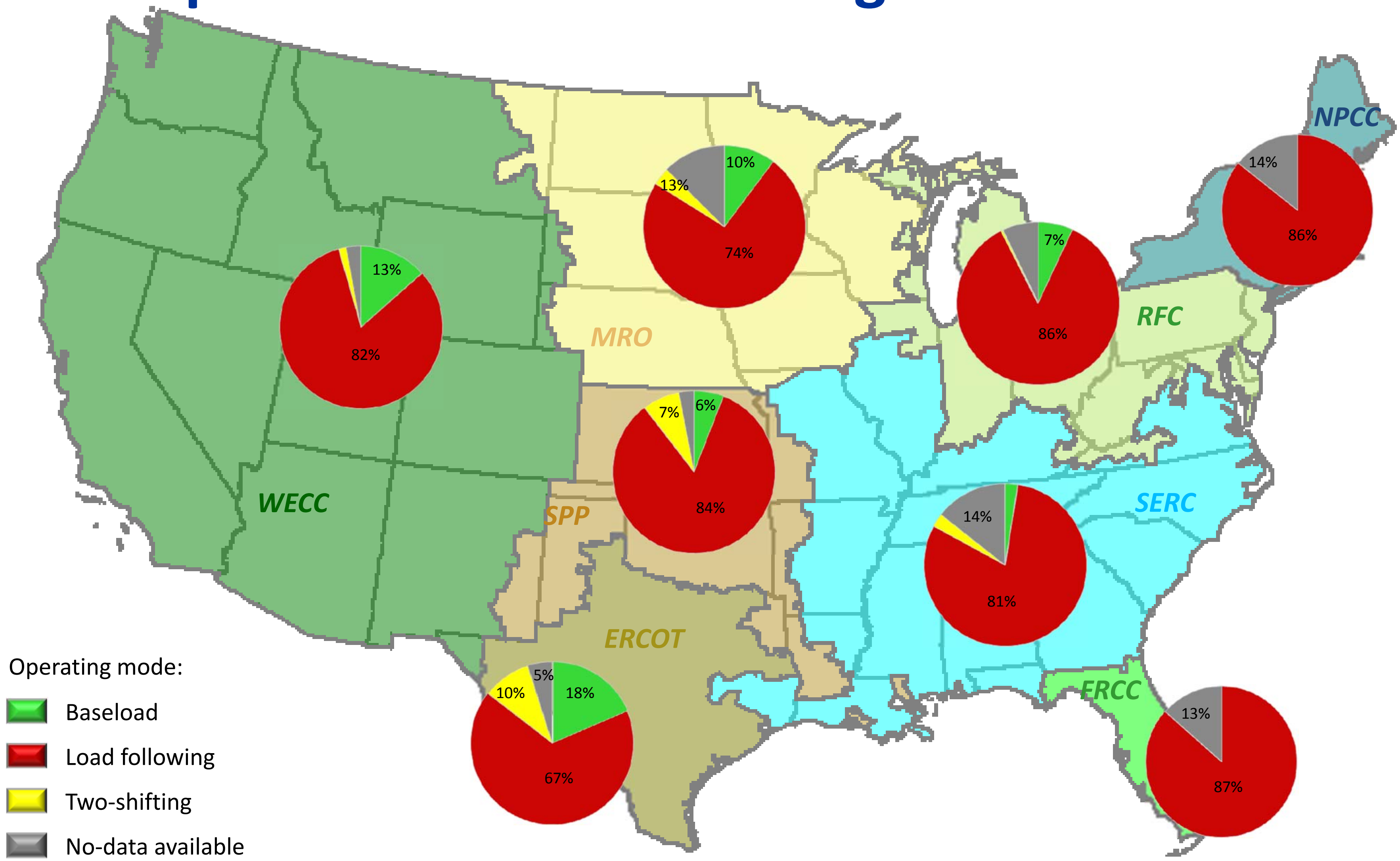
- ✓ Aggregate coal capacity was 20,176 Mw
- ✓ Average coal capacity factor was 74 %
- ✓ Average coal spinning reserve was 2,230 Mw

- ✓ Peak Load was 65,782 Mw
- ✓ System load factor of 55 %

- ✓ Average wind and other supply was 3,239 Mw
- ✓ Max Wind Output was 7,109 Mw



# Large number of coal power plant units were operated in load following mode in 2013



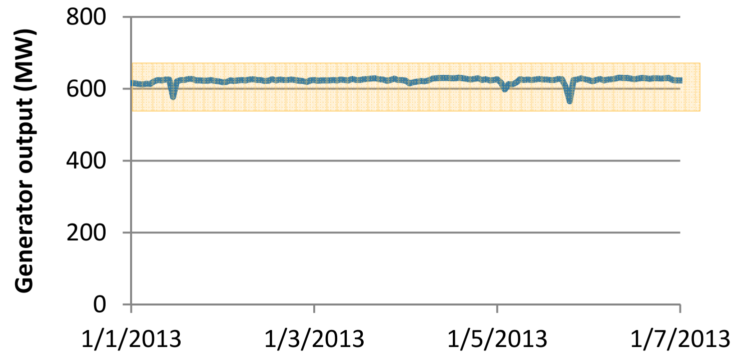

*Note: Numbers represent % of the coal generation capacity in the area*



*Data source: Velocity suite*

# Coal power plant can work in three (four) different modes

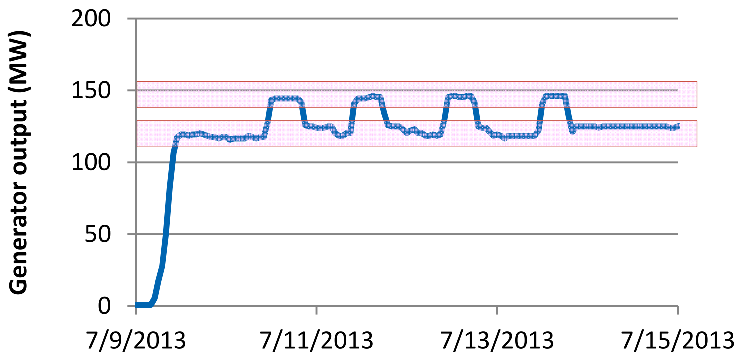
**Baseload:** Operate around a set point 24/7



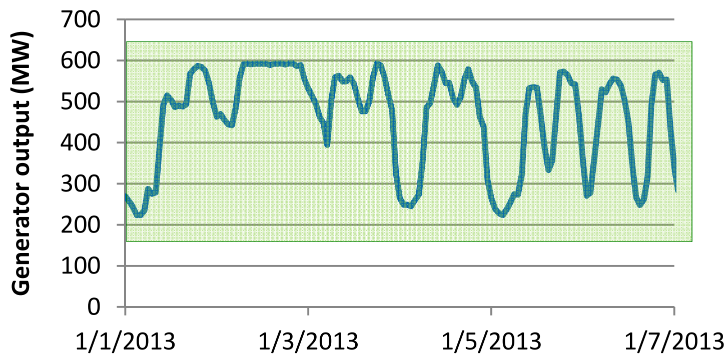

**Peaking:** Operate during peak hours

To be added if we find any …

**Two-shifting:** operate around two set points

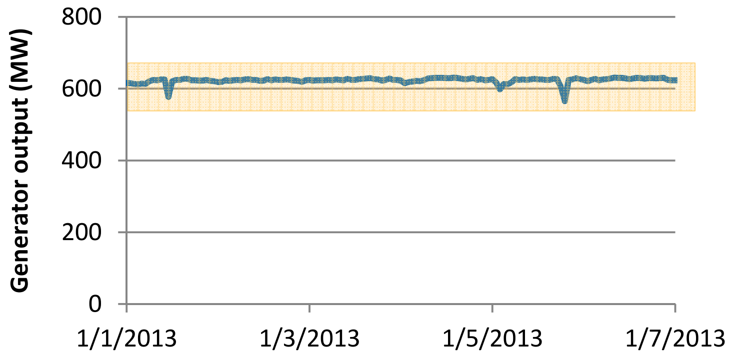


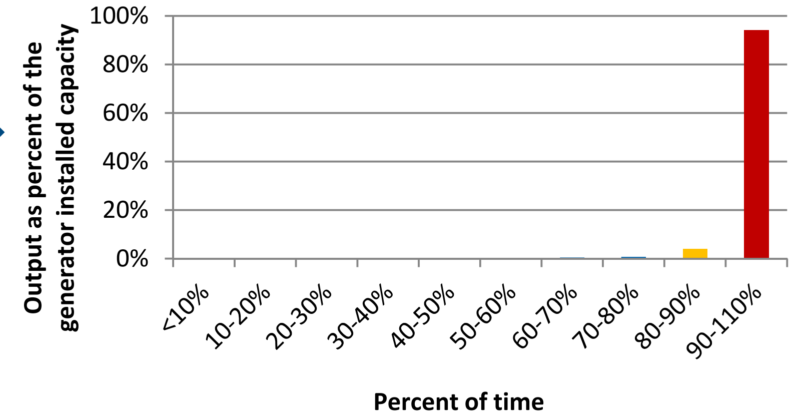

**Load following:** Operate in a wide range



# Mode of a generator unit is determined based on generation output statistic

**Baseload:** Operate around a set point 24/7

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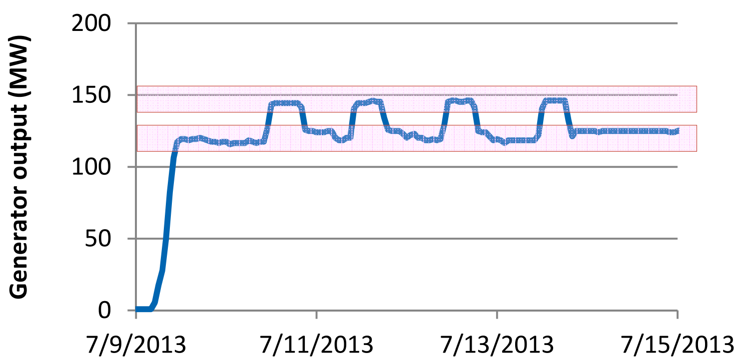
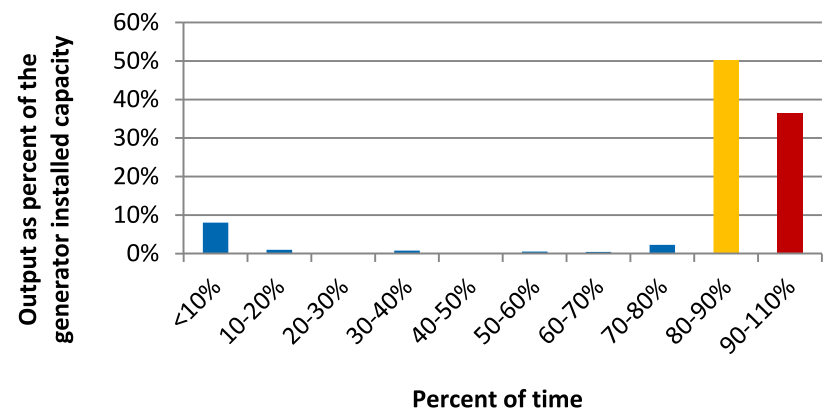
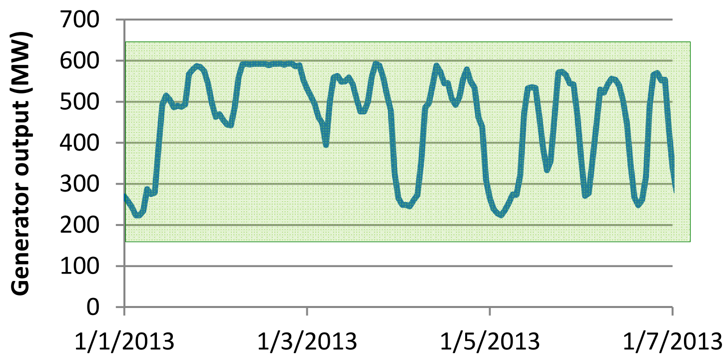
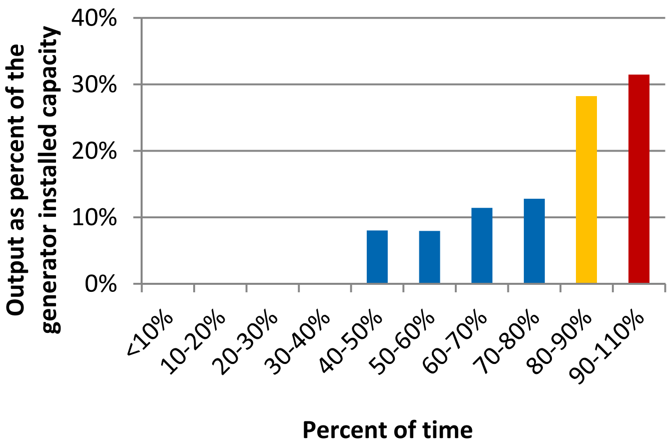


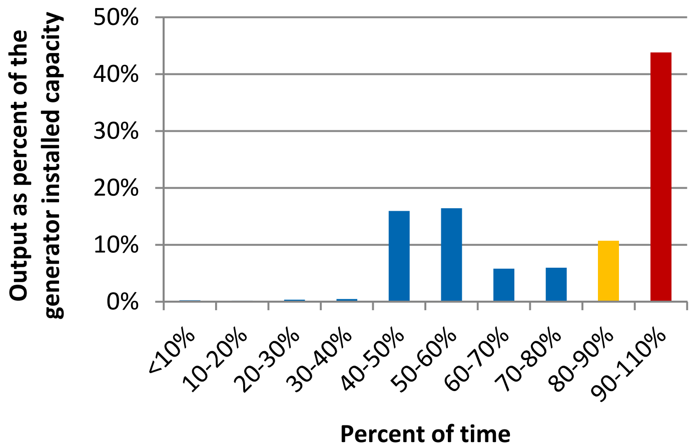



# Mode of a generator unit is determined based on generation output statistic (cont.)

**Load following:** Operate in a wide range



# Load Following in ERCOT

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 3% | 5% | 7% | 8% | 9% | 10% | 11% |
| 1 | | | | | | | | | | | | | | | Startup | LF1 |
| 2 | | | | | | | | | | | | | Startup | LF1/BL | LF1/TS | BL |
| 3 | | | | | | | | | | | | | Startup | LF1/BL | LF1/BL | BL |
| 4 | | | | | | | | | | | | Startup | BL | BL | BL | BL |
| 5 | | | | | | | | | | | | Startup | BL | LF1/BL | LF1/BL | LF1/BL |
| 6 | LF1/BL | LF1/BL | LF1 | LF1 | LF3 | LF1 | LF3/BL | BL | BL | BL | BL | BL | BL | BL | BL | BL |
| 7 | BL | LF1/BL | BL | LF3/BL | LF1/BL | BL | BL | BL | BL | BL | BL | BL | BL | LF1/BL | LF1/BL | BL |
| 8 | BL | BL | BL | LF1/BL | LF1/BL | BL | BL | LF1/BL | LF1/LF3 | LF1 | LF1/BL | LF1/LF3 | LF1 | LF1/BL | LF1/TS | LF1/BL |
| 9 | BL | LF3/BL | BL | LF1/LF3 | LF1/LF3 | BL | BL | BL | BL | BL | BL | LF1/LF3 | LF1/BL | BL | LF1/BL | LF1/BL |
| 10 | BL | BL | BL | LF1/LF3 | LF1/LF3 | BL | BL | BL | BL | BL | BL | LF1/LF3 | LF3/BL | LF1/BL | LF1 | LF1 |
| 11 | BL | BL | BL | LF1/BL | LF3/BL | BL | BL | BL | BL | BL | LF3/BL | LF3/BL | LF3 | LF1/BL | LF3/BL | LF1/BL |
| 12 | BL | BL | BL | LF3/BL | LF3/BL | LF1/BL | LF1/BL | BL | BL | LF1/BL | LF1/BL | LF1/BL | LF3 | LF1/LF3 | LF3/TS | LF1/LF3 |
| 13 | BL | BL | BL | LF3/BL | LF3/BL | BL | BL | BL | BL | BL | LF1/BL | LF1/BL | LF1 | LF3/BL | LF3/TS | LF1/LF3 |
| 14 | BL | BL | BL | LF3/BL | LF3/BL | BL | LF1/BL | BL | BL | BL | LF1/BL | LF1/BL | LF1 | LF3/BL | LF3/TS | LF1/LF3 |
| 15 | LF1 | LF3 | LF3 | LF3/BL | BL | BL | BL | BL | BL | BL | BL | TS/BL | LF1/BL | LF1/BL | TS/Down | TS |
| 16 | LF1 | LF3 | LF3 | LF1/LF3 | LF1/BL | BL | BL | BL | BL | BL | LF1/BL | LF1 | LF1/BL | LF1/BL | TS/Down | TS |
| 17 | BL | BL | BL | LF1 | LF1 | LF1/BL | LF1/BL | LF1/BL | LF1/LF3 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1/LF3 | LF1 |
| 18 | BL | BL | LF1 | LF1/BL | LF1 | BL | BL | LF1/BL | LF1/LF3 | LF1 | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1 | LF3/TS | LF1 |
| 19 | LF1/BL | LF1/BL | LF1/BL | LF1 | LF1 | LF1/BL | LF1 | LF1/BL | LF1/BL | LF1/BL | LF1/BL | LF1/BL | LF1/LF3 | LF1/TS | F3/TS/Dow | LF1/LF3 |
| 20 | LF1/BL | LF1/BL | LF1/BL | LF1/BL | LF1 | LF1/LF3 | LF1/BL | BL | LF3/BL | LF1/BL | LF3/BL | LF3/BL | LF3 | LF3/TS | TS/Down | TS/BL/Dow |
| 21 | LF1/BL | LF1/BL | LF1/BL | LF3 | LF3 | LF3/BL | LF3/BL | LF3/BL | LF3/BL | LF3/BL | LF3/BL | LF3/BL | LF3 | LF3/TS | TS | TS/Down |
| 22 | LF3/BL | BL | LF1/Down | LF1 | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF3/BL | LF1/BL | LF3/BL | LF3/BL | LF3/BL | LF3 | LF1/LF3 | LF1/LF3 | LF1/LF3 |
| 23 | LF3/BL | LF1 | LF1/BL | LF1/Down | LF1 | LF1/BL | LF1/BL | LF1/BL | LF1/BL | BL | LF3/BL | LF1/BL | LF1/LF3 | LF1/LF3 | LF1 | LF1/LF3 |
| 24 | LF3/BL | LF1/BL | BL | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1 | LF1 | LF1 | LF1/BL | LF1/BL | LF3/BL | LF1/LF3 | LF1/LF3 | LF1 | LF1/LF3 |
| 25 | LF3/BL | LF1/LF3 | LF1/LF3 | LF3/BL | LF1/LF3 | LF1 | LF1 | LF1/BL | BL | BL | LF1/BL | LF1 | LF1/BL | LF1 | LF2/TS | LF2/TS |
| 26 | LF1 | LF1/BL | LF1/BL | LF1/Down | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1/LF3/BL | LF1/BL | LF3/BL | LF1/LF3/BL | LF1/LF3/BL | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1 |
| 27 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1/LF3 | F3/TS/Dow | LF1/TS | LF1/LF3/TS | LF3/TS | LF3 |
| 28 | LF1/LF3 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1/LF3 | LF1/LF3 | LF3 | LF3 | LF1 | LF3 | LF1/LF3 | LF3 | LF1/LF3 | LF1/LF3 |
| 29 | LF1/LF3 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1 | LF1/LF3 | LF3 | LF1 | LF1/BL | LF1 | LF1 | LF1/LF3 | LF1/LF2/LF3 | LF3/TS |
| 30 | LF1/LF3 | LF1 | LF1/BL | LF1 | LF1 | LF1/BL | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1/LF3 | LF1 | LF1/LF3 | LF1/LF3 | LF1/TS | LF1/LF3 | LF1/LF3 |
| 31 | LF3/TS | LF3/TS | LF1 | LF3 | LF1 | LF1 | LF3 | LF3 | LF3 | LF3 | LF1/LF3 | LF3 | LF1 | TS | TS | LF3/TS |
| 32 | TS | TS | LF1 | LF3 | LF1 | BL | LF1 | LF1/BL | LF1/BL | LF1 | LF1 | LF3 | LF1 | LF3/TS | LF3/TS | LF3/TS |

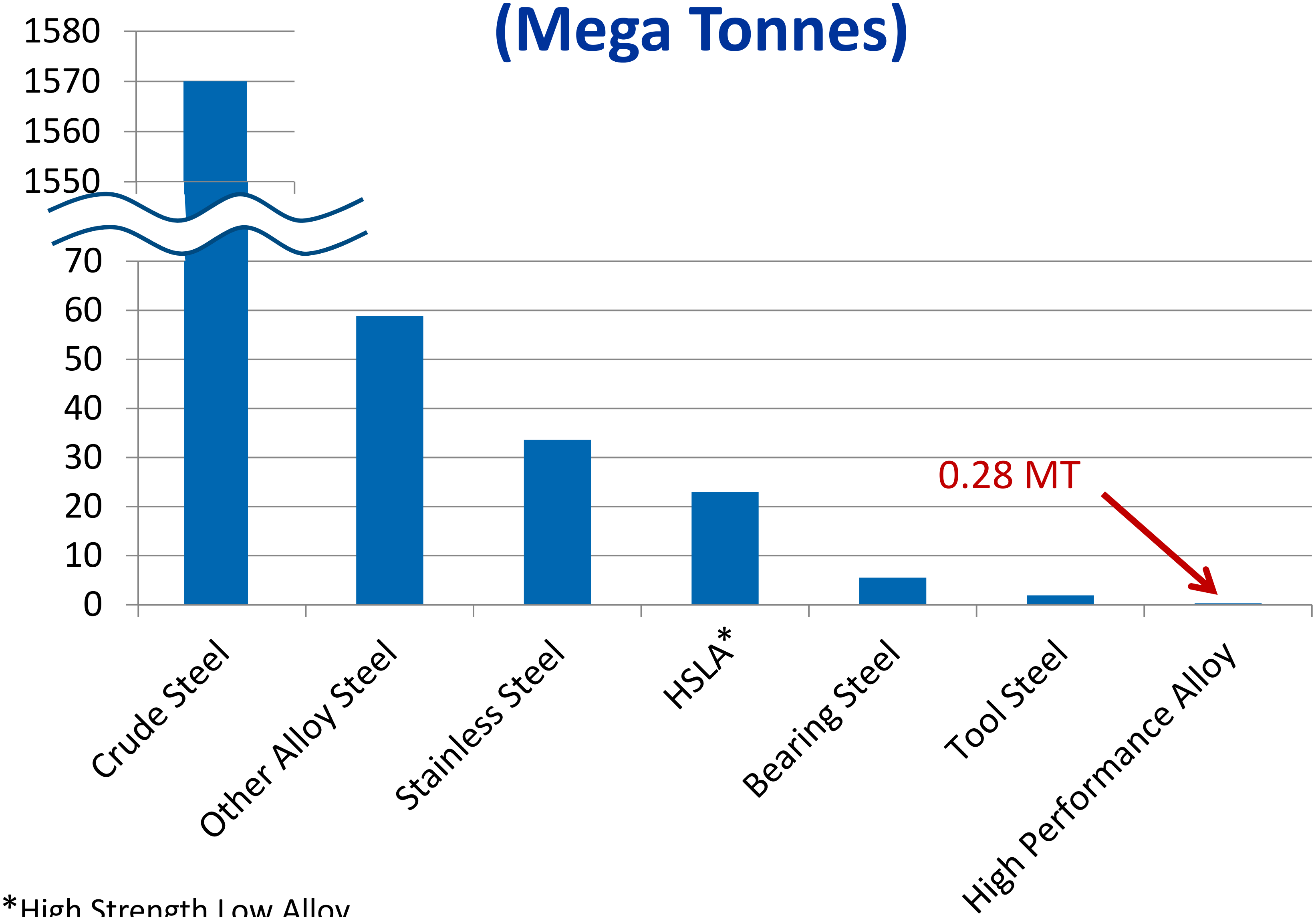
# Load Following Component Issues

| Components | Concerns |
|---|---|
| Boiler | • Economizer fatigue failures<br>• Lower furnace tubes fatigue failure<br>• Superheater/Reheater header – creep, fatigue, oxidation, thermal shock, and differential expansion<br>• Superheater/Reheater component damages, attemperator spray unable to keep up with temperature changes<br>• Boiler Drum nozzle fatigue |
| Steam Turbine | • Unbalanced heating due to steam admission valves<br>• Turbine rotor defects<br>• High water droplet erosion<br>• Last stage blade "stall flutter" vibration |
| FGD | • Fatigue/creep on absorber linings |
| Generator | • Accelerated fatigue/creep on retaining ring |
| Balance of Plant | • Water chemistry issues<br>• Reduced motor life due to cycling<br>• Pipe thermal stress<br>• Tube grooving in heat exchangers |

# Crosscutting Analysis Projects

- Economic Opportunity for the Existing Coal Fleet to Refurbish with Advanced Sensors and Controls
  - http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Potential-Impact-of-Improved-Sensors-Controls.pdf
  - http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Benefits-of-Advanced-Sensors-and-Controls.pdf
- Economic Opportunity for Advanced Material Boiler Tubes – Draft Report Complete
- Assessment of Sensors, Controls and Advanced Materials in Load Following Coal Units– Summer 2014
- **Global Advanced Materials Market Assessment – Summer 2014**
  - **Market Outside of Coal Power Sector**
  - **International – AUSC**
- Computational Modeling Benefits– Summer 2014

# 2012 Global Metal Market Breakdown (Mega Tonnes)

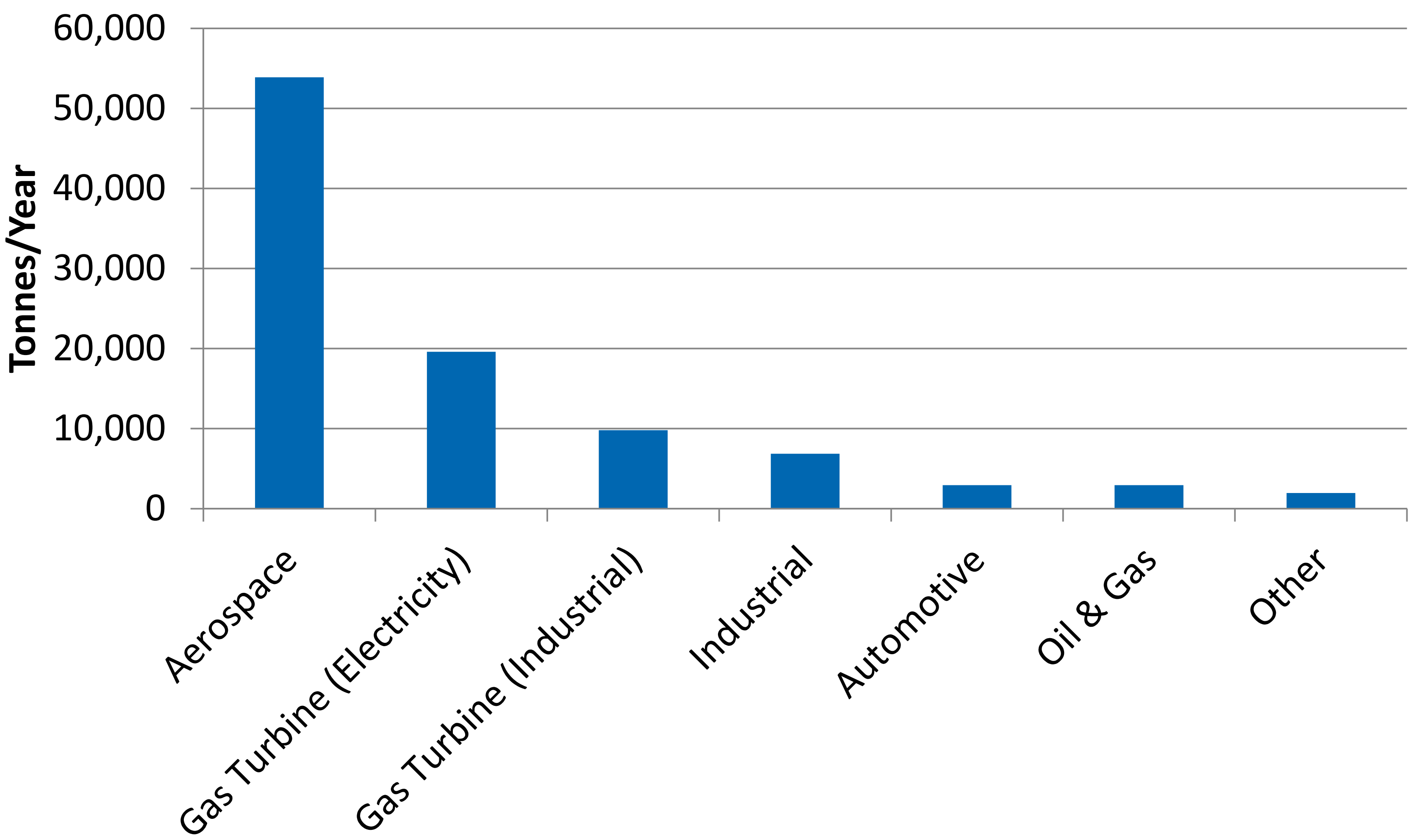



*High Strength Low Alloy



*Into the Melting Pot: The Superalloy and its Impact on Minor Metals, Roskill Information Services Ltd., Presented Feb. 28, 2013 at Minor Metals Conference, Accessed 12/5/13* www.roskill.com

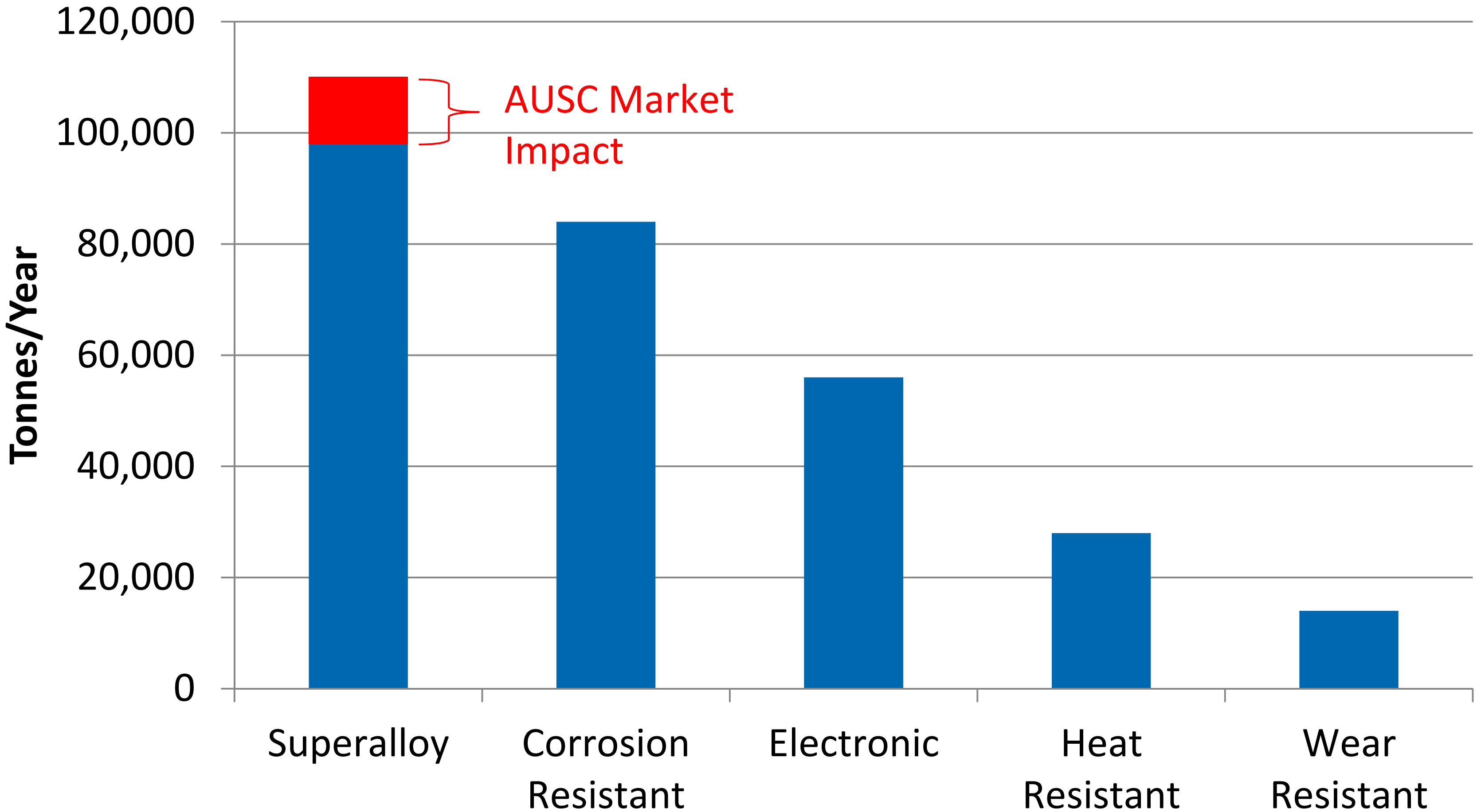
# Superalloy Global Market Distribution






*Into the Melting Pot: The Superalloy and its Impact on Minor Metals, Roskill Information Services Ltd., Presented Feb. 28, 2013 at Minor Metals Conference, Accessed 12/5/13 www.roskill.com*

# High Performance Alloys Global Market Breakdown




AUSC Market Assumes 20% of new global coal builds in the World Energy Outlook from 2025-2035 are AUSC. Consistent with market penetration of USC.



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# Advanced Materials Market Assessment - International Market Methodology

1. Determine the potential number of AUSC plants to be constructed internationally
2. Determine the form of advanced materials to be shipped overseas (bulk materials, fabricated components, finished products)
3. Quantify amount of export opportunity
4. Determine impact on US economy
5. Quantify "other" benefits (engineering, fabrication, environmental, etc.)

# Advanced Materials International Market Assessment – Estimated Economic Impacts

- **These results should be viewed as a low case since the U.S. is only taking credit for the value of the materials and not the value of the entire product.**
- **Adds roughly $1.5-$1.7 Billion to the U.S. economy each year from 2020-2035**
- **Supports roughly 5000 additional jobs at a compensation of about $70k**

# Crosscutting Analysis Projects

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- **Computational Modeling Benefits– Summer 2014**

# Computational Modeling Benefits Assessment Steps

1. **Understand NETL's computational modeling program**
2. **Literature Review**
   - Qualitative/anecdotal studies
   - Studies that quantify benefits - accelerate R&D, skip intermediate-scale testing, reduce R&D costs, increase the chance of success of R&D.
3. **Talk to industry/academia to determine how they use computational models in their R&D efforts and how this benefits them.**
4. **Determine if industry and NETL have the same views on computational modeling and if NETL is meeting industry needs.**
5. **Quantify/illustrate the specific benefits of computational modeling in applications such as: developing materials, National Risk Assessment Partnership (NRAP) initiative, Carbon Capture Simulation Initiative (CCSI)**

# Quantitative Economic Impacts

- Report on the economic impact of computational modeling, simulation, and visualization (MS&V) in the Hampton Roads region of Southeastern Virginia

  - MS&V cluster contributed $413 million annually to the region's output in 2004. Projected to increase to $764 million in 2009.
  - The MS&V cluster accounted for $248 million in gross regional product (GRP) in 2004. Projected to increase to $482 million in 2009.
  - MS&V cluster generates slightly over 4,000 jobs in Hampton Roads each year. Projected to increase to nearly 7,000 new jobs in 2009.
  - The largest fraction of the cluster generated jobs, 2,700, are in the service sector. Other sectors experiencing a significant increase in employment include retail trade, 628 jobs, construction, 289 jobs, and finance, insurance, and real estate, 134 jobs.
  - MS&V cluster contributed to a regional increase in population of 765 people in 2004. This is projected to increase to over 4,300 people in 2009.



http://dls.virginia.gov/commission/pdf/HRPDC%20Report%202005%20M&S.pdf

# Benefits of Computational Modeling

## *Examples with qualitative and quantitative information*

| Sector | Description | Quantitative Information |
|---|---|---|
| Pandemic Vaccine Decision-making[1] | The 2009 H1N1 pandemic demonstrated that modeling can help answer questions about new vaccine development, distribution, and administration, such as (1) is a vaccine needed; (2) what characteristics should the vaccine have; (3) how should the vaccine be distributed; (4) who should receive the vaccine and in what order; and (5) when should vaccination be discontinued? | Mathematical and computational modeling fast forwarded the new vaccine development, production, distribution, and administration time-line from multiple years to six months. |
| Beverage Can Industry[2] | Used supercomputer complex modeling and simulations to redesign aluminum cans for the beverage industry, as well as components for the automotive, aerospace, building, and construction industries. Simulations that used to take weeks on in-house workstations were completed in minutes on the supercomputer | Cut $100k for lab work for redesigning a can to just $2k using the supercomputer. Saved about $200m annually by reducing the metal required for can manufacture |
| Crop Hybrid Seed Development[3] | Utilized supercomputing to manage and analyze huge amounts of data for large-scale number crunching and statistical analysis of the data, and for modeling and simulations to chart a course of action, such as prediction of new hybrid seed development (i.e., predicted the future of seed breeding programs) | Sped-up answers to research problems, from days and weeks to hours |



2. Council on Competitiveness. (2008). "High Performance Computing Drives a "Can-Do" Attitude at Alcoa."
3. Council on Competitiveness. (2009). "Pioneer is Seeding the Future with High Performance Computing."

# Benefits of Computational Modeling

## *Examples with qualitative and quantitative information*

| Sector | Description | Quantitative Information |
|---|---|---|
| Ford Motor Company[1,2] | Modeled whole vehicles to evaluate multiple attributes; reduction in the number of component tests required for assurance testing; reduced modeling time; increased virtual capability with physical correlation; and brought new products to market faster | 15%-25% reduction in new cylinder head or block development time; projected to have saved Ford up to $100 million in cost avoidance and between $2 million and $5 million per year in reduced testing requirements and development time; provides an estimated combined ROI over 7:1 |
| Pratt-Whitney[2] | Used this approach to optimize the design and manufacturing of jet engine turbine rotors | System life-cycle benefits of ~$200 million for a typical turbine engine application and fleet; reductions of $3 million in the cost of design data testing with a sixfold reduction in test costs; ROI of nearly 10:1 |
| Boeing[2] | Used computational modeling to aid in airframe design and manufacturing | Estimates a reduction in material certification time by 20-25% (3-4 years) |
| Goodyear[3] | Computational modeling streamlined the Goodyear design routine; innovated more rapidly; quicker introduction of leading-edge products; partnering with Sandia National Labs for product development | Reduced key product design time from 3 years to <1 year; expenditures on tire building and testing dropped from 40 % of the company's research, design, engineering and quality budget to 15% |

*National Research Council. Available at: **http://www.nap.edu/catalog/12199.html***

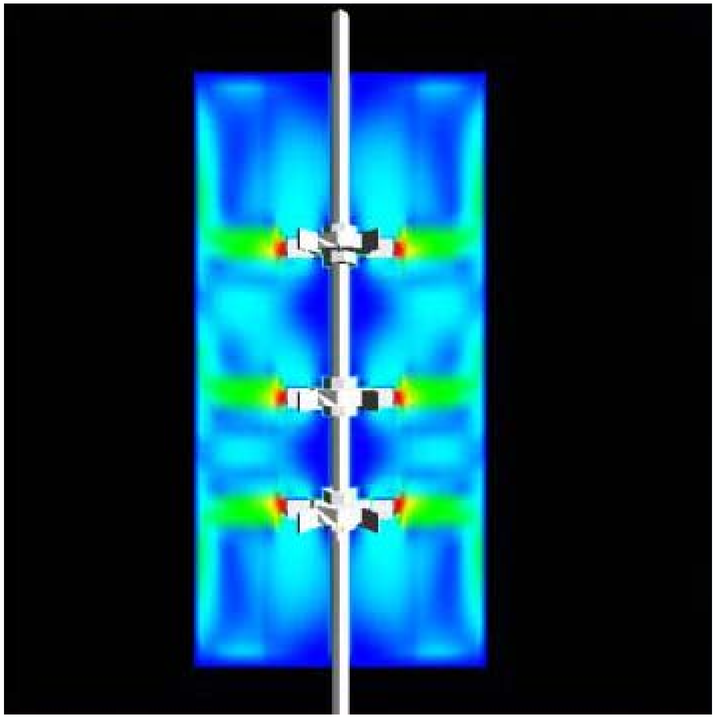
3. *Goodyear Puts Rubber to the Road with High Performance Computing, Council on Competitiveness (2009). Available at: http://www.compete.org/publications/detail/685/goodyear-puts-the-rubber-to-the-road-with-high-performance-computing/*

# Summary Spreadsheet
## *Computational Modeling*

| Tools Developed | Technology Application | Number of license issued / users | Patents issued or pending | Link to NETL application/papers | Outside Applications (Industries) | Benefit Metrics |
|---|---|---|---|---|---|---|
| MFIX | Chemical Looping, Carbon capture, Oxycombustion, Nuclear waste treatment, Gasification, Fluid Bed Combustion | 3358 | NA | https://mfix.netl.doe.gov/ | Chemical, Gas/oil, Renewable, Geologic, Nuclear, any industry or application with dense, reacting multiphase flow | CO2 reduction, efficiency, new process design and process optimization |
| C3M | Gasification, Chemical Looping, Oxycombustion | 59 | NA | https://mfix.netl.doe.gov | Chemical, Power | Reduce the uncertainty in performance predictions and reduce the development cost of scaling up of reactors |
| VE-Suite | Open source virtual engineering software toolkit, | 15 listed organizations, estimated 6,400 downloads | NA | http://www.vesuite.org | Power, Design, Training | Allows designs, analysis, training to be completed/tested in a virtual environment |

# VE Suite Impact

- **Job creation**
  - Several spinoff companies created in areas of engineering visualization, data analysis
- **Training**
  - Virtual Paint - Models spray gun to allow students to paint in a virtual world without creating VOC emissions
- **Engineering**
  - U.S. Army - Immersive Engineering has reduced the design cycle time and cost to allow new products to reach production and operation quicker than previously thought possible



# Thank You!

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