

# REINHOLD ENVIRONMENTAL®



## **2025 Reinhold/PCUG Round Table Presentation**

Hosted by AEP and Buckeye Power

in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

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# Navigating Generation Flexibility and Cost Management Challenges

Round Table: Workshop 13

Stephen Storm  
2025 Reinhold Environmental Conference  
June 23, 2025 (2:45PM - 3:45PM)  
Columbus, Ohio



# 2025 Generation Portfolio

ARP Program  
Supplemental Program  
Strategic Supplemental Project



## THERMAL FLEET

- 214: Boiler Life and Availability Improvement
- 215: Power Plant Piping
- 216: Gas Turbine Life Cycle Management
- 217: Gas Turbine Advanced Components and Technologies
- 218: Heat Recovery Steam Generators
- 219: Steam Turbines and Auxiliary Systems
- 220: Generators and Auxiliary Systems

## RENEWABLE FLEET

- 206: Wind Generation  
*Environmental Aspects of Wind (SP250)*  
*Offshore Wind (SP249)*
- 207: Solar Generation  
*Environmental Aspects of Solar (SP252)*
- 208: Hydropower Generation  
*Geothermal*

## NEXT-GENERATION FLEET

- 221: Bulk Energy Storage
- 222: Advanced Generation and Carbon Capture and Storage  
*Generation Transitions (SP248)*  
*Low-Carbon Resources Initiative*  
*Net-Zero Industrial Clusters*

## THERMAL OPTIMIZATION & EMISSIONS CONTROLS

- 223: Heat Rate and Flexibility: Generation Fleet Optimization
- 232: SCR Performance Issues
- 233: Continuous Emissions Monitoring and Measurements  
*Combustion and Carbon Control Issues (SP254)*  
*Emissions Controls (SP253)*

## WATER & LAND MANAGEMENT

- 238: Water Treatment Technologies
- 239: Aquatic Resource Protection
- 240: Water Quality and Effluent Guidelines
- 241: Byproducts Management and Market Development
- 242: Groundwater and Land Management

## FLEET MANAGEMENT & OPERATIONS

- 224: Integrated Asset Management
- 225: Plant Management Essentials
- 226: Boiler and Turbine Steam and Cycle Chemistry  
*Plant Decommissioning and Site Redevelopment (SP255)*

## AIR QUALITY & HEALTH

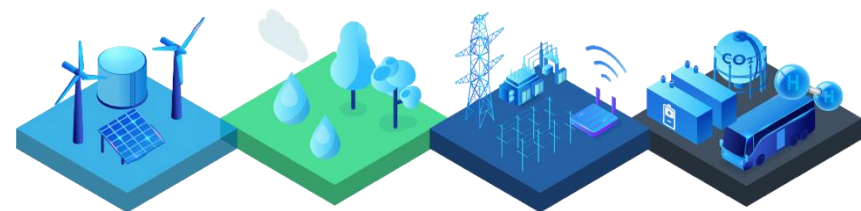
- 235: Air Quality Assessments and Multimedia Characterization
- 236: Air Quality, Health, and Communities

## DIGITALIZATION

- 209: Cyber Security for Generation Assets
- 227: Process Control and Automation
- 228: Monitoring and Advanced Data Analytics  
*Digital Transformation Research Initiative*

## MATERIALS

- 229: Materials  
*Advanced Manufacturing*



# Thermal Optimization

## Heat Rate and Flexibility: Fleet Generation Optimization



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- Program Management
- Holistic Optimization
- Trouble-Shooting
- Combustion Optimization
- Boiler Performance
- Heat Rate and Flexibility Improvement

- Heat Rate and Flexibility Improvement
- Power Cycle Design and Performance Evaluations
- Heat Exchangers: FWBs
- Cooling Systems
- Plant Upgrades and Modifications

- Fleet Optimization and Strategy:
  - Flexibility
  - Resiliency
  - Sustainability
- Energy Transition
- Cost Management
- Reliability and Risk Management

- Global focus on coal and environmental considerations
- Energy transition and emission policy in emerging Asia
- Emission monitoring and control, especially mercury
- Technology and knowledge transfer to regions in transition

# Emissions Controls

## Gas, Coal and Low Carbon Fuels



Tony Facchiano  
Senior Technical  
Executive



Jose Sanchez  
Principal Tech. Leader



Sylvio Cardoso  
Technical Leader



Alex Jimenez  
Sr. Technical Leader



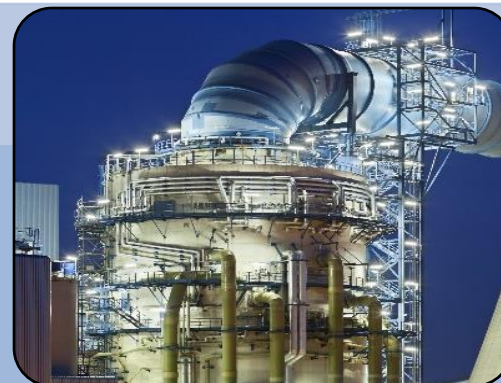
Cassie Shaban  
Sr. Technical Leader



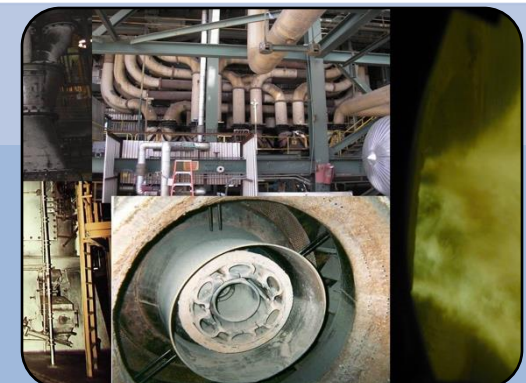
P232  
SCR Performance for Gas and  
Other Fuels



P233  
Emissions Measurement &  
Monitoring for Gas and other Fuels



SP253  
Emissions Control for Coal  
and Other Fuels

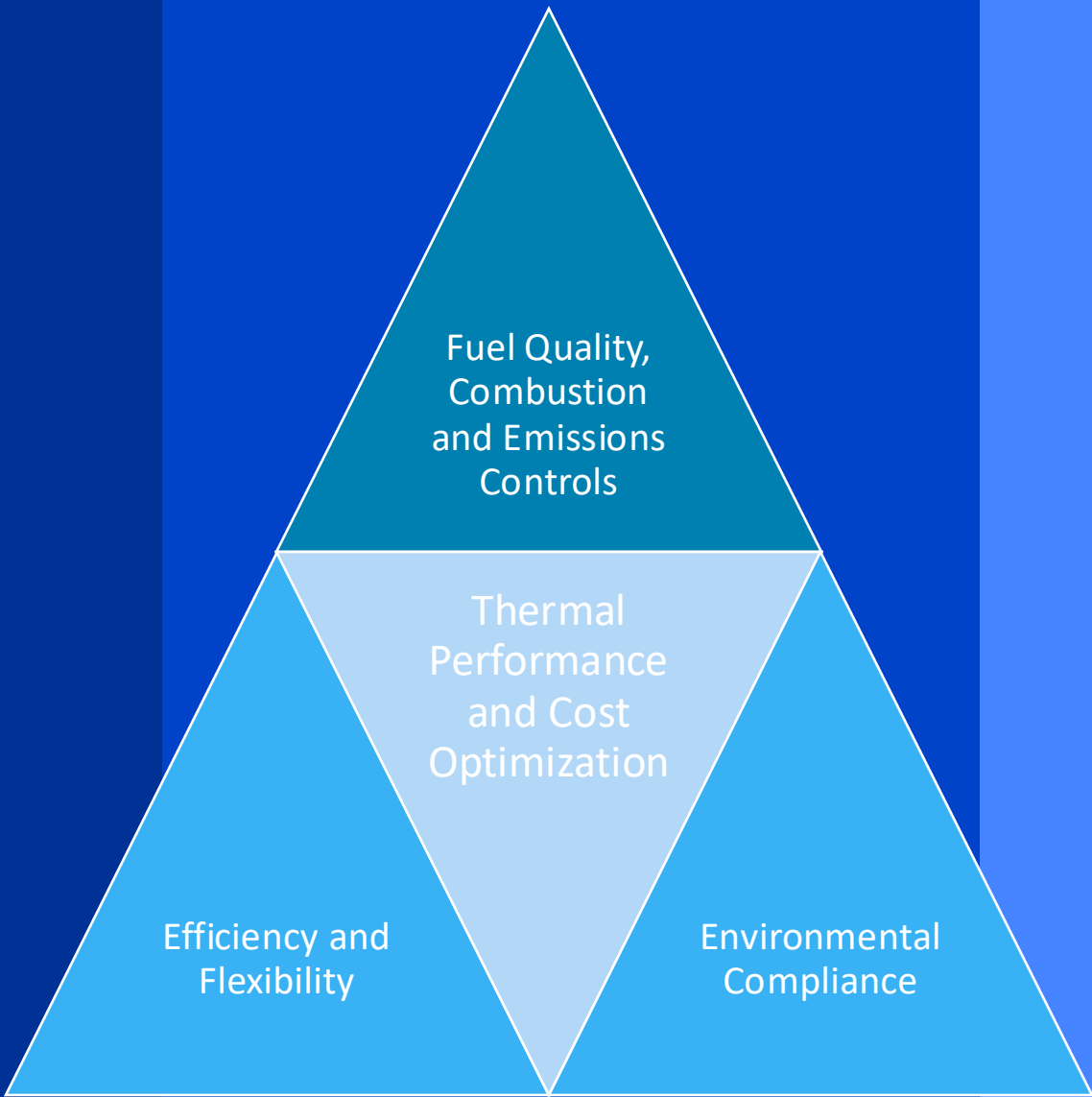


SP254  
Combustion and Carbon  
Control for All Fuels

# Thermal Optimization and Emissions Controls

- **Fuels Quality and Combustion** (fossil fuels (oil, gas, coal). **Low carbon fuel strategies** (co-firing and transitions)

- **Heat Rate and Flexibility, Generation Fleet Optimization**



- **Emissions Controls** (NO<sub>x</sub>, SO<sub>x</sub>, Hg)
- **SCR Performance Issues** (Conventional steam plants, CCGT units, Simple Cycle units, RICE)
- **Continuous Emissions Monitoring and Measurements**

# Non-Dispatchable vs. Dispatchable Power Generation

Flexible operation of conventional and combined cycle thermal plants will continue to increase rapidly with the adoption of new variable energy, renewable resources, and other changes in the generation landscape.

Cycling refers to the operation of electric generating units at varying load levels, including on/off and low load variations, in response to changes in system load requirements. The increasing need for on/off operation of dispatchable coal and gas plants impacts heat rate, reliability, and flexibility.



**Non-Dispatchable**



**Semi-Dispatchable**



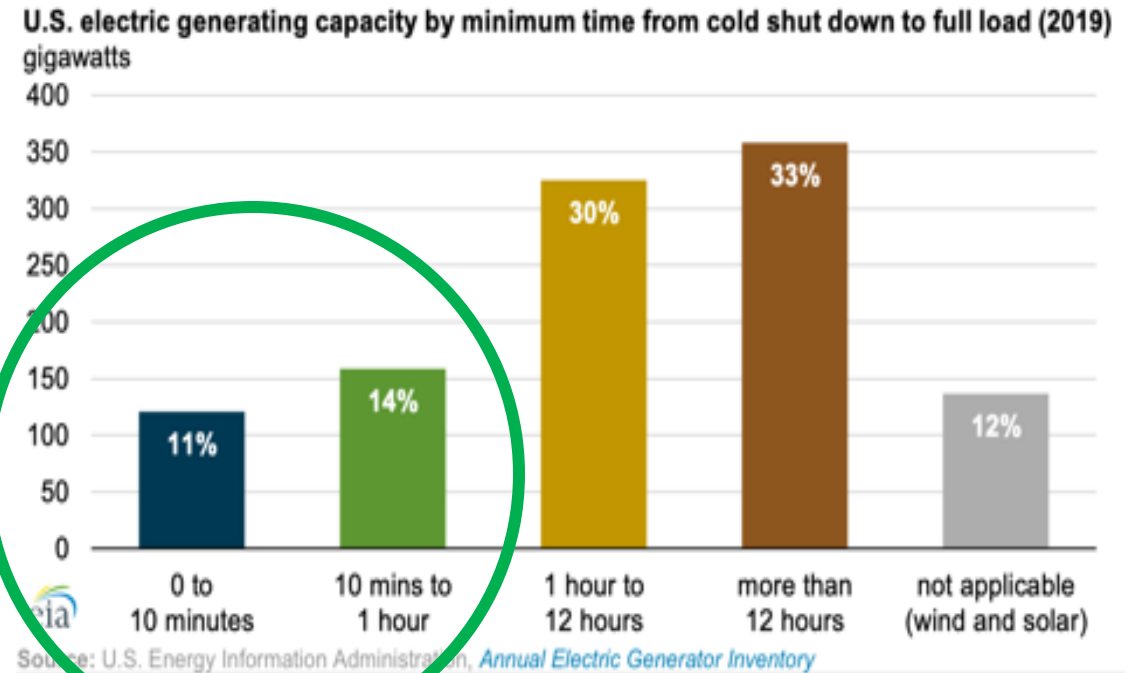
**Dispatchable**

# Benchmarking Generating Asset Capabilities

	On/Off	Ramp Rate	Minimum Load
Coal (Subcritical)	Possible 2-5h lead time (Not typically done)	0.6-4%/minute (avg. 1%)	20-55% (avg. 38%)
Coal (Supercritical) Constant Pressure	Not done	0.6-4%/minute (avg. 1%)	40-70% (avg. 52%)
Coal (Supercritical) Sliding Pressure	Possible 2-5h lead time (Not typically done)	1-8%/minute	20-40%
Combined Cycle	<b>Possible 1-4h lead time</b>	<b>0.8-15%/minute (avg. 3%)</b>	10-70% (1x1 ~65%, 2x1 ~55%, 3x1 ~45%)
Simple Cycle	<b>Possible 0.1-1h lead time</b>	<b>7-30%/minute (avg. 14%)</b>	35-60%
Hydroelectric	<b>Possible, &lt;0.1h lead time</b>	<b>15-25%/minute</b>	5-6%
Reciprocating Engines	<b>Routinely done 0.1h lead time</b>	<b>25%/minute</b>	Modular

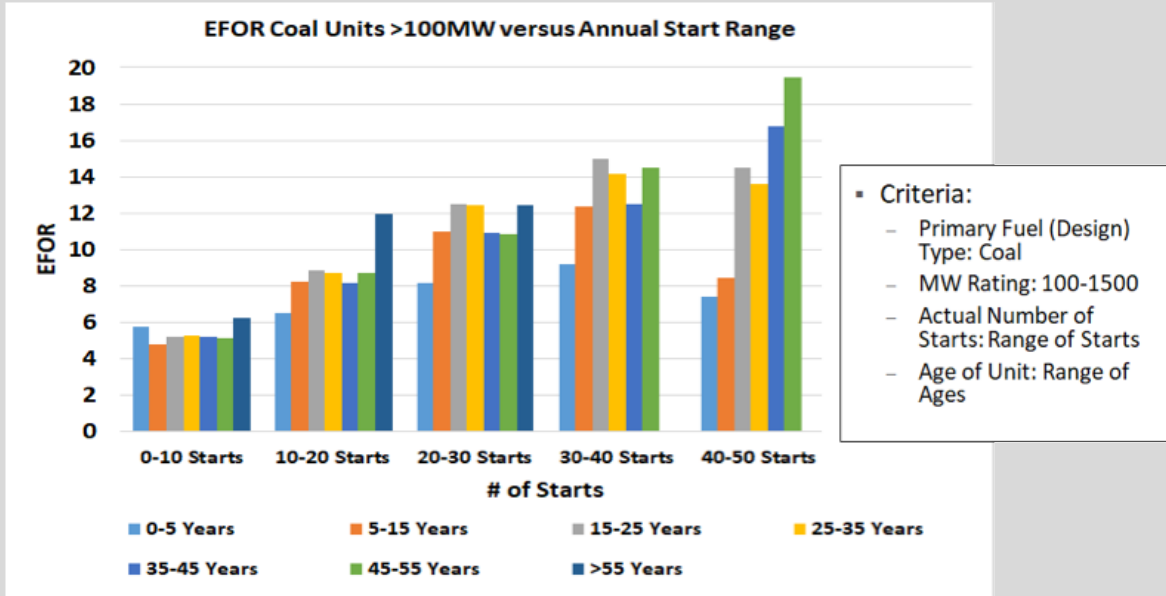
**Asset Mix**

**Flexibility Demand**

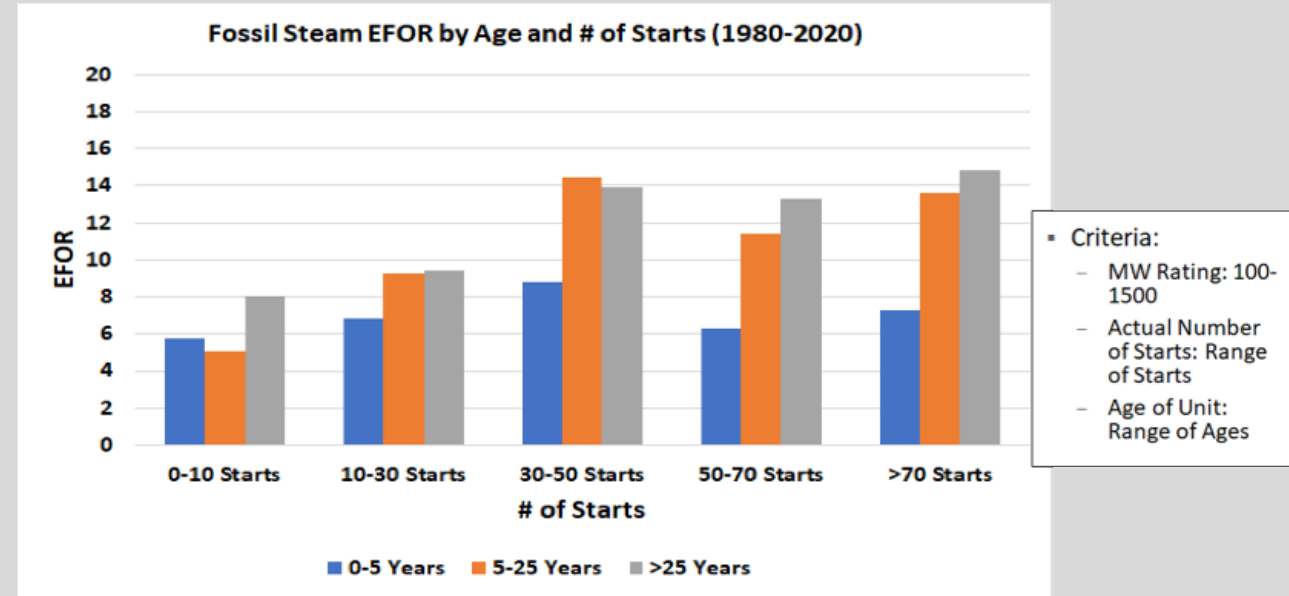


# Units by Starts and Age

## Conventional Coal



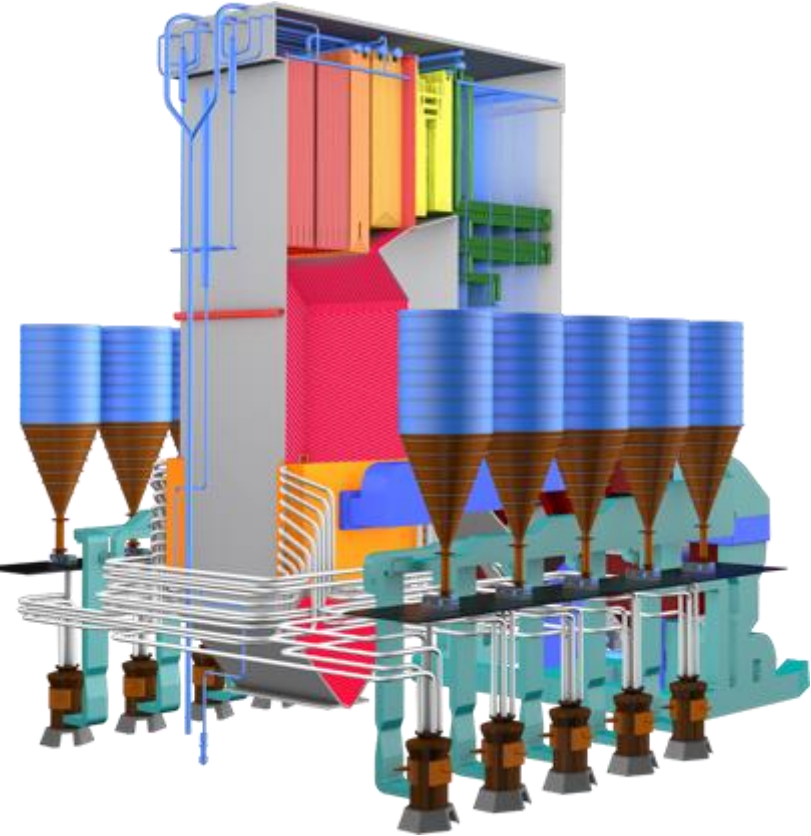
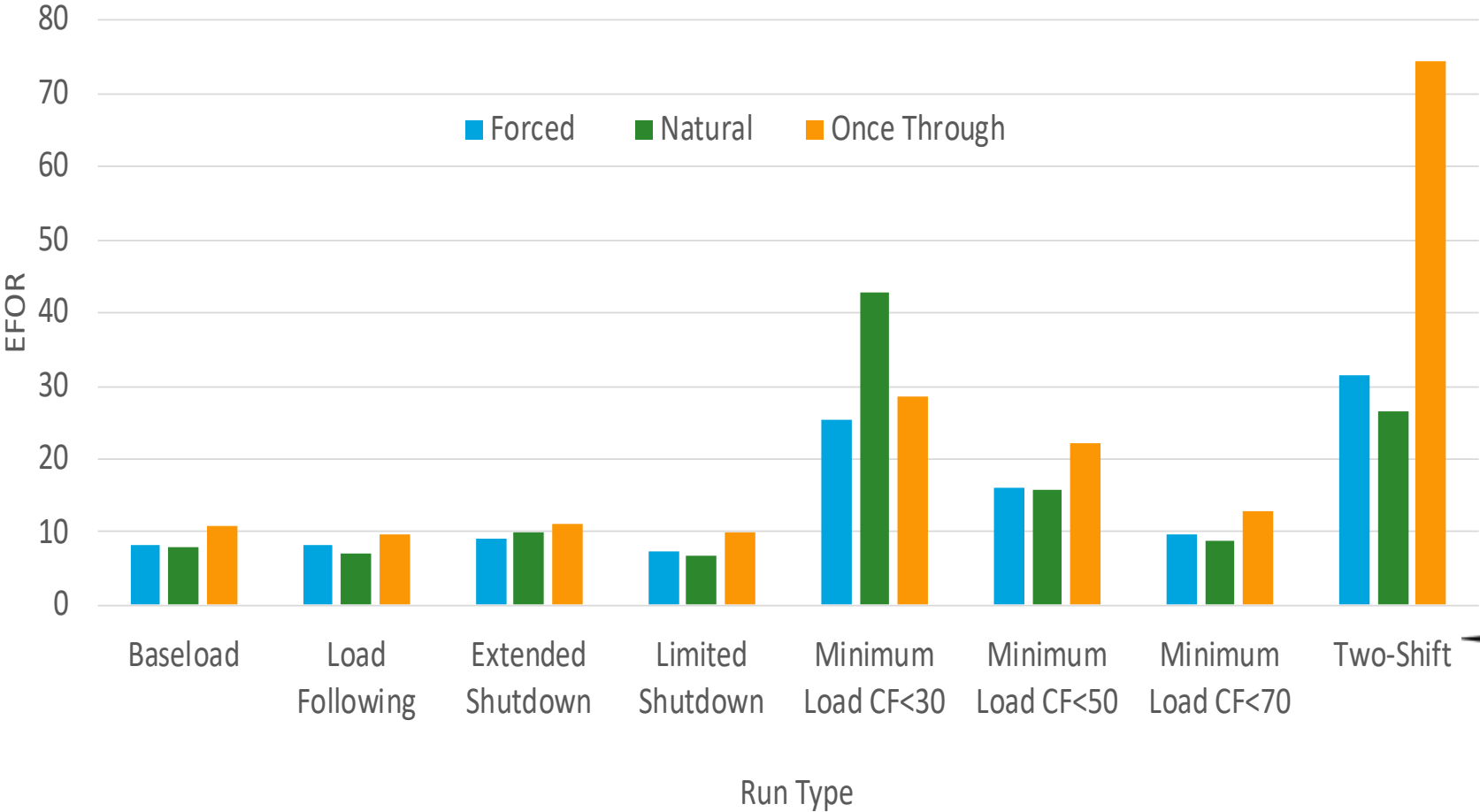
## Combined Cycle



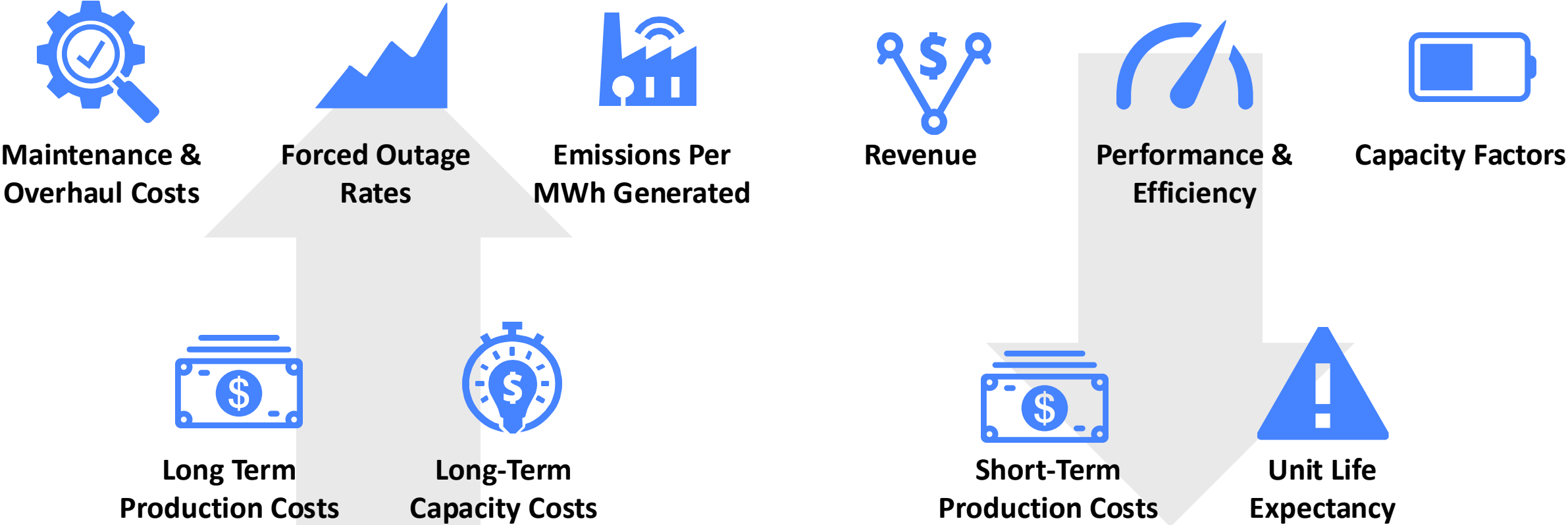
Interrelationships of Heat Rate and Flexibility  
 NERC GADS: Assessment of 40 Years (1980-2020), 3002023069

# GADs Data Study (4 decades of data)

Conventional coal units are negatively affected by cycling and transient operating conditions. A GADS data study of the US fleet that spans four decades revealed that the aging boiler's reliability is most impacted with reduced minimum load and 2-shift operations.



# Economic & Reliability Impacts of Flexible Operation



**Technical Challenges Drive Commercial Impacts**

# Managing the Cost of Flexible Operations



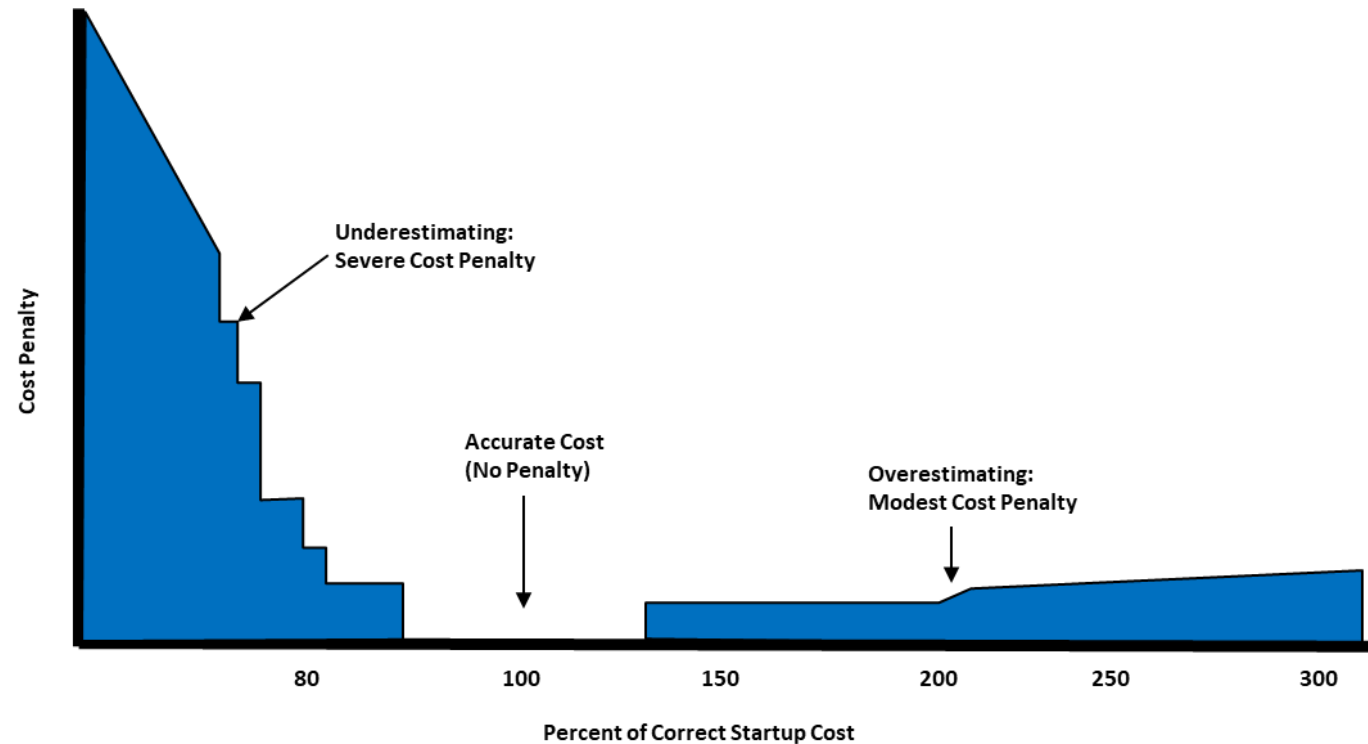
- **Lumpy Costs of Flexible Operation**
  - Flexible operation challenges vulnerable systems
  - Cycling costs are incurred as performance reduction and increased failure rates
  - Decision making can be improved by relating per-start/per cycle costs to long-term O&M activities



- **Valuing Flexibility**
  - Relate **damage** rate, **failure** rates, and **cost**
  - Flex costs can go **unrecognized and unrecoverable**
  - **Alignment among stakeholders**



- **Long-term market & regulatory uncertainty/risk**
  - Energy markets are dynamic
  - Regulatory priorities can shift
  - Consider **low-cost strategies** that provide **benefit across a range of scenarios**

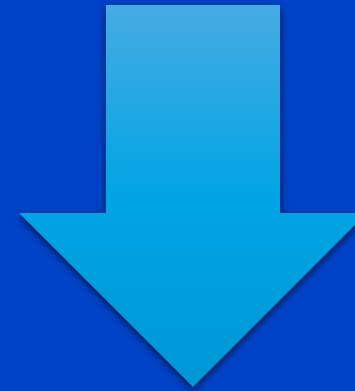


# Flexibility Challenges

- The efforts behind improving heat rate and flexibility require a broad understanding of power plant design, operation, maintenance, ambient conditions, thermal-hydraulics, combustion, plant processes, measurement techniques, controls, materials, and fuel types.



# Balancing Demands



Fixed Cost of Generation  
Ancillary Services Demand  
Demand for Flexibility  
Equipment Vulnerability  
Emissions per MW  
Start-up Fuels (Oil, Gas)  
Auxiliary power ( per MWH)  
Financial Constraints



Plant Load Factors  
Generation Revenue  
Efficiency  
Reliability  
Load stability



# Balancing Market Implications with O&M Best Practices

Thermal Fatigue

Layup Corrosion

Corrosion Fatigue

Creep Fatigue

Low-Cost Fuels

Heat Rate Degradation

Operator Challenges

Environmental Control Issues

Layup O&M

Balance of Plant O&M

Training and Awareness

Fuels Flexibility Strategy

Diagnostic and Digital Strategy

Alarm Management

People Resource Management

Inspections and Life Assessment

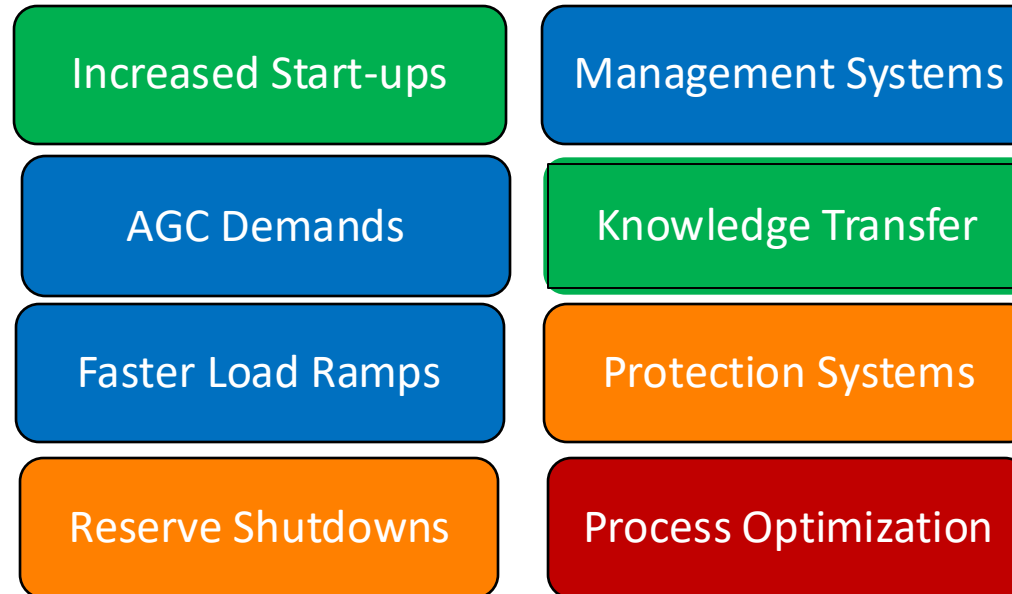
Controls and Sensors

Improved Layups

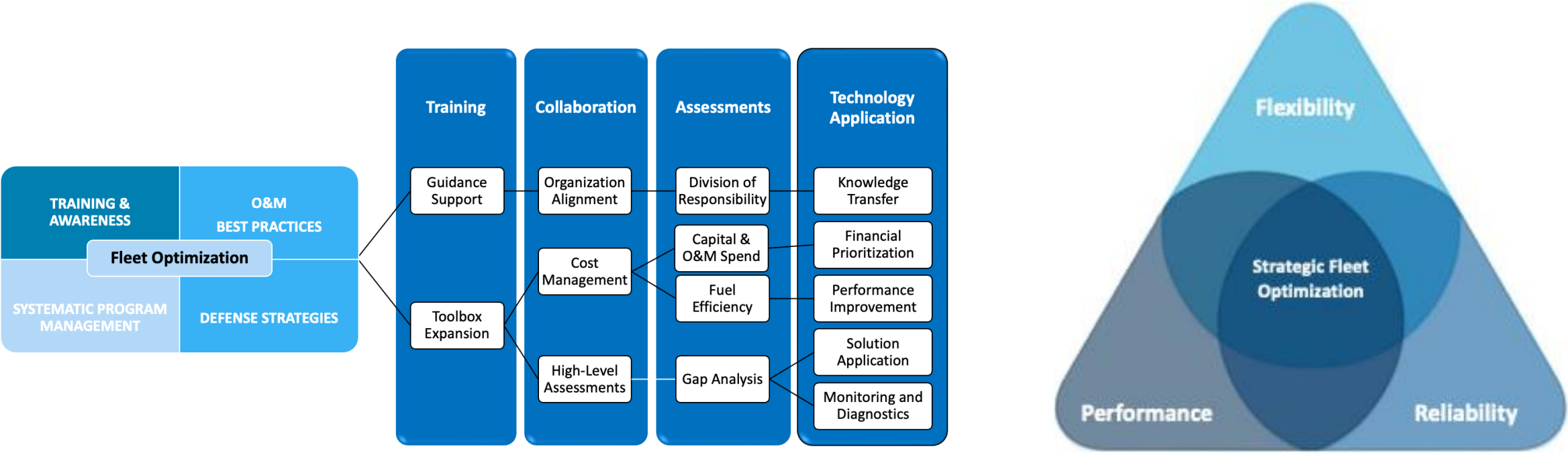
Damage Tracking

Process Optimization

Heat Retention

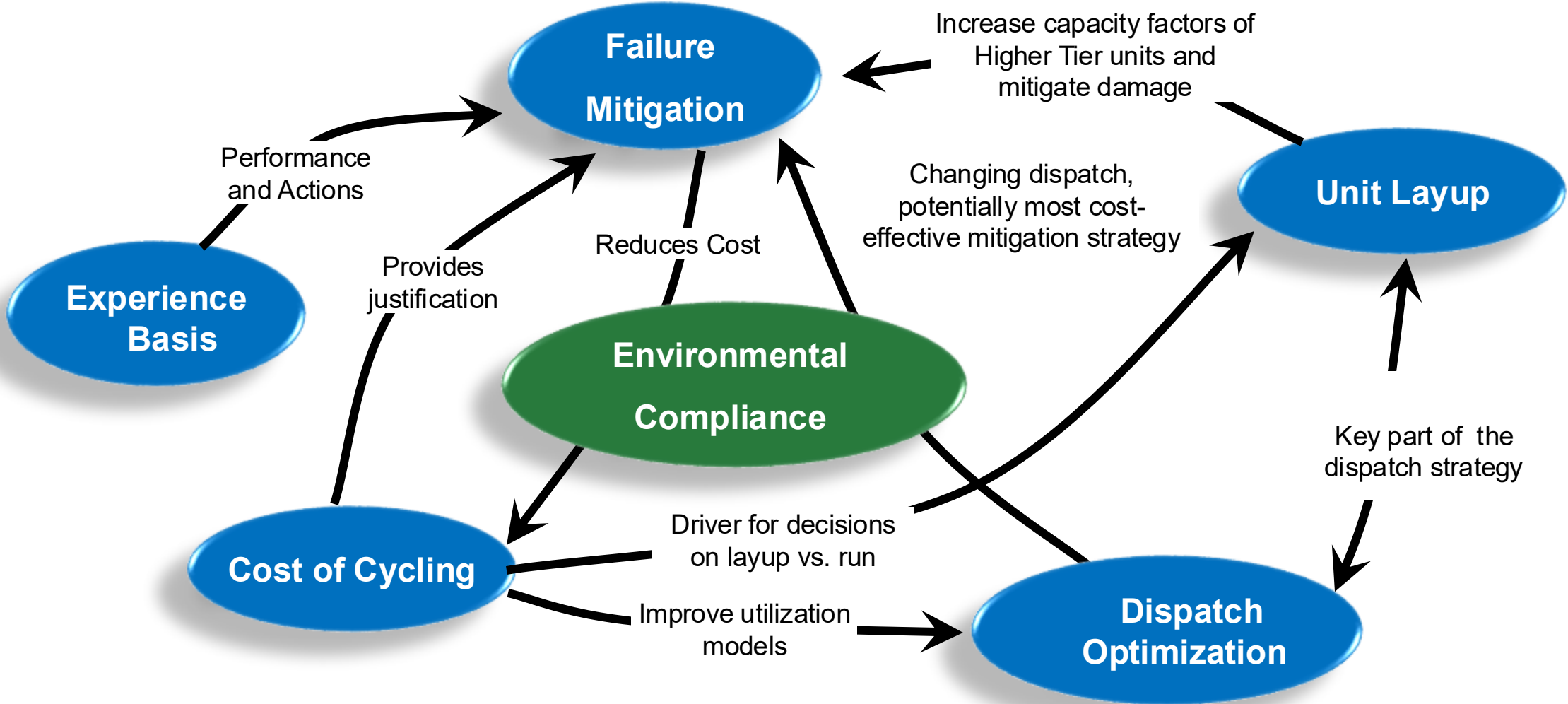


# Demystifying the Complexity of Flexible Operations



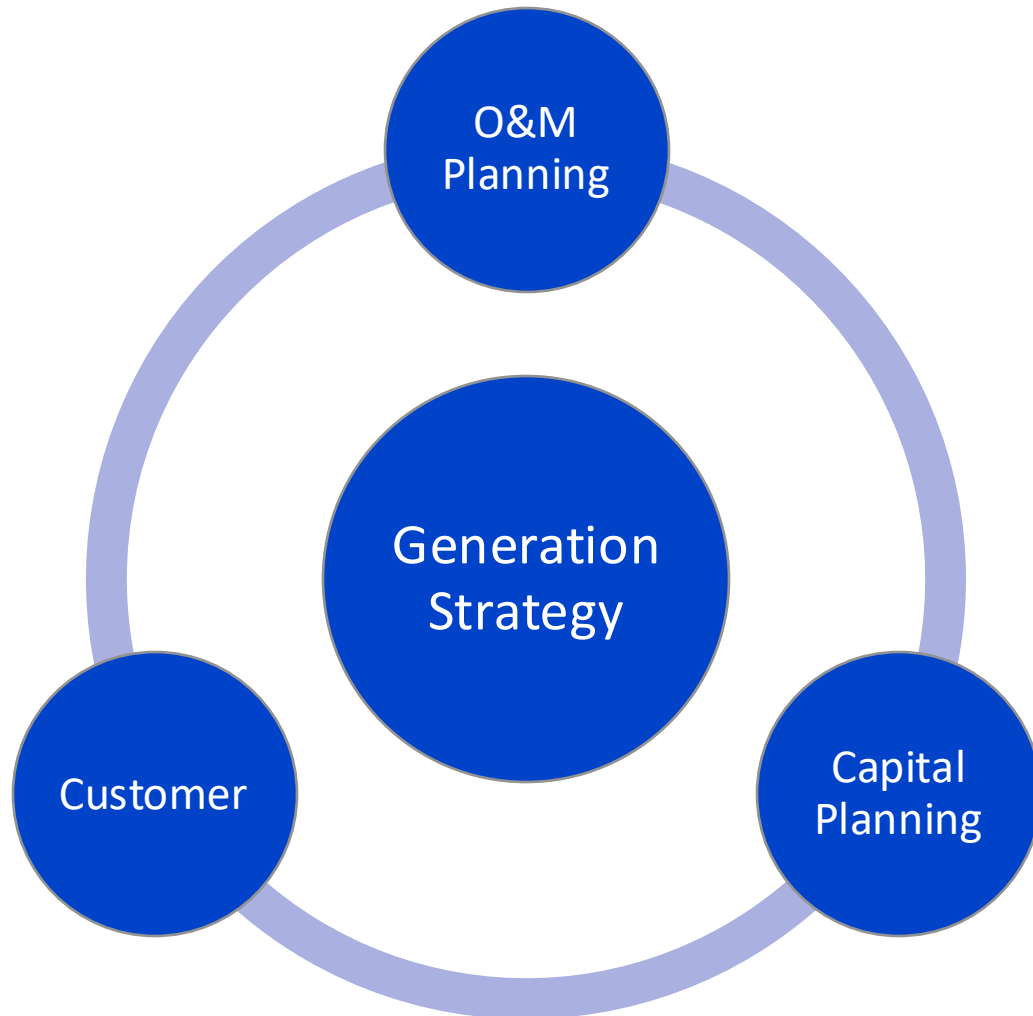
Integrating a programmatic approach

# Holistic Optimization



Integrating and aligning operational and/or maintenance strategies that help minimize or mitigate the risks associated with flexible operation are critically important. From an emissions standpoint, heat rate improvement should always be the first obvious step to reduce CO<sub>2</sub> and ALL other emissions. Heat Rate improvements save fuel, increases generation capacity, reliability and results with improvements to reduce air emissions which are one-for-one (e.g., 2.5% heat rate improvement = 2.5% reduction in all air emissions, including carbon dioxide [CO<sub>2</sub>] and nitrogen oxide [NO<sub>x</sub>])

# Align Fleet Optimization Strategy



## Manage & Negotiate:

### Reliability

Maintain high reliability through the transition by identifying and managing risks.

### Technology

Advance the generating fleet state of technology to meet the system needs.

### Cost

Minimize costs of the transition through financial planning and long-term technology plans.

- **And...**
  - **And...**
    - **And...**

# Aligning People, Process and Technology

The reliability and flexibility of dispatchable thermal generation stations is interrelated with performance of various subsets of equipment, operational and maintenance actions. Those actions are driven by people, process and the application of technologies that assist with a complex interplay which is required to ensure performance sustainability and market availability.



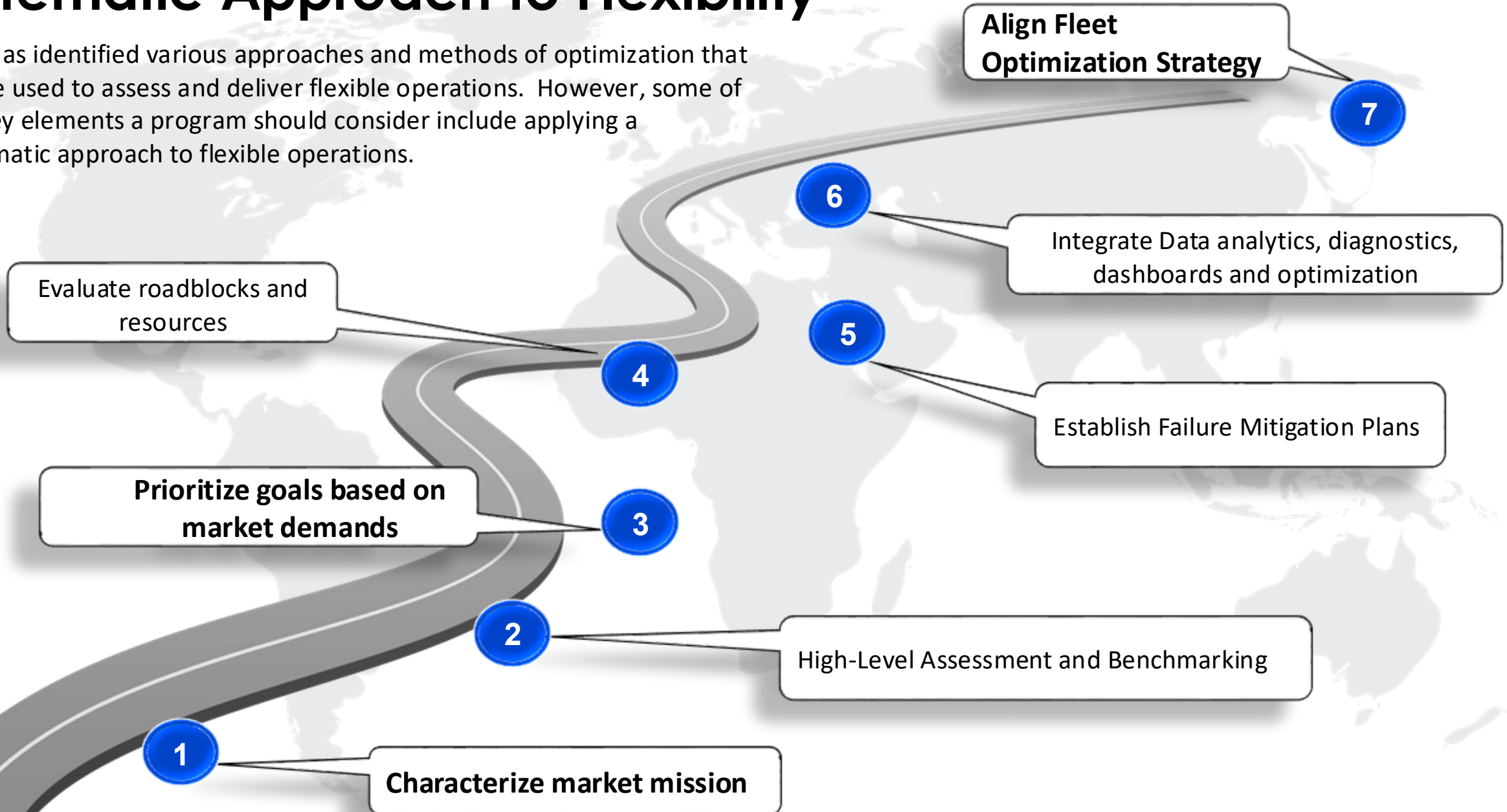
Operational Procedure  
Training, Monitoring  
Inspections, Programs

Water Chemistry (core instrumentation, alarms)  
Condensate Polishing, Corrosion Mitigation  
Protection Systems, Lay-up Program, Asset  
Integrity and Predictive Maintenance

Sensors  
Diagnostics  
Automation  
Dynamic Optimization

# Systematic Approach to Flexibility

EPRI has identified various approaches and methods of optimization that can be used to assess and deliver flexible operations. However, some of the key elements a program should consider include applying a systematic approach to flexible operations.



# Characterize Market Mission



FASTER RAMP RATES



LOWER MINIMUM LOADS



FASTER START-UP TIMES



SHORTER MINIMUM UPTIME AND RUN TIMES

Increased VRE puts more stress on dispatchable generation flexibility to support net load peak days or net load minimum days to avoid VRE Curtailment.

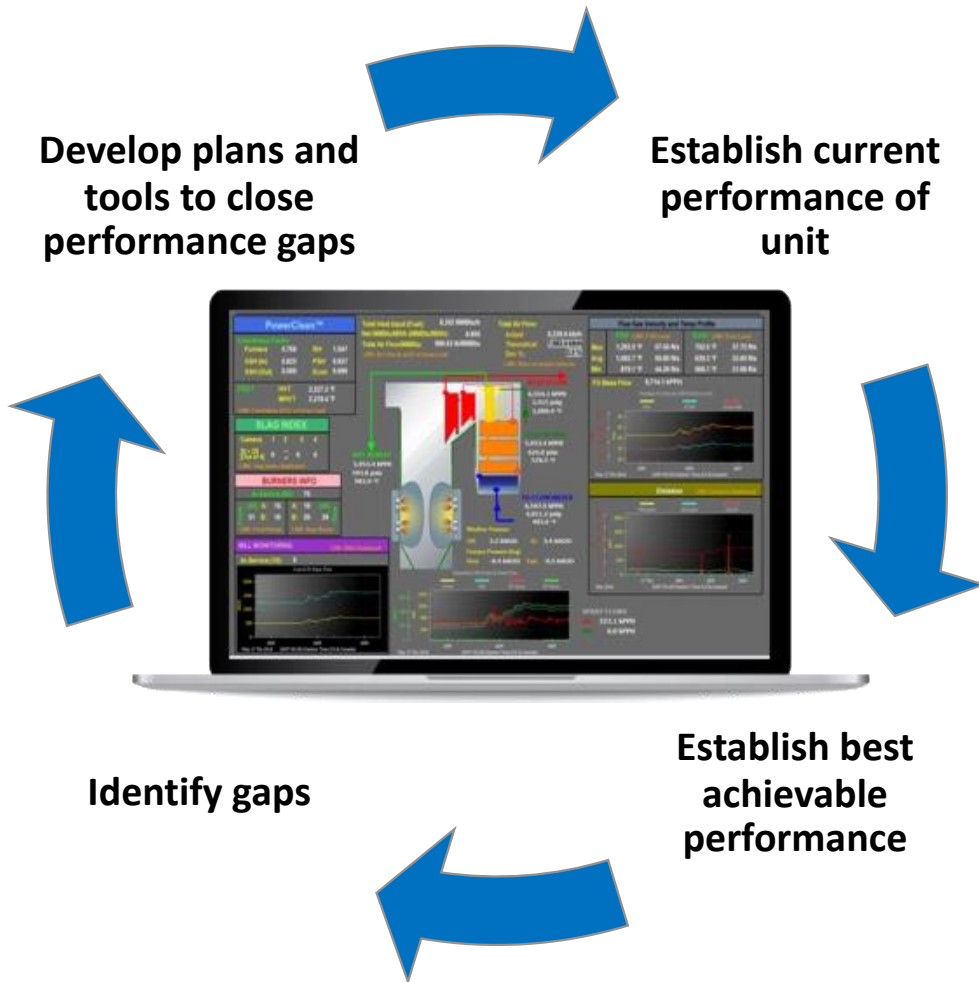
## Net Load Peak Days

- All units required to meet the peak
- Often hottest or coldest days
  - Limits output and efficiency

## Net Load Minimum Days:

- Units needed to turn down or shut down but prepared to respond
  - Can be offline for days before being required

# Integrated Heat Rate and Flexibility Management



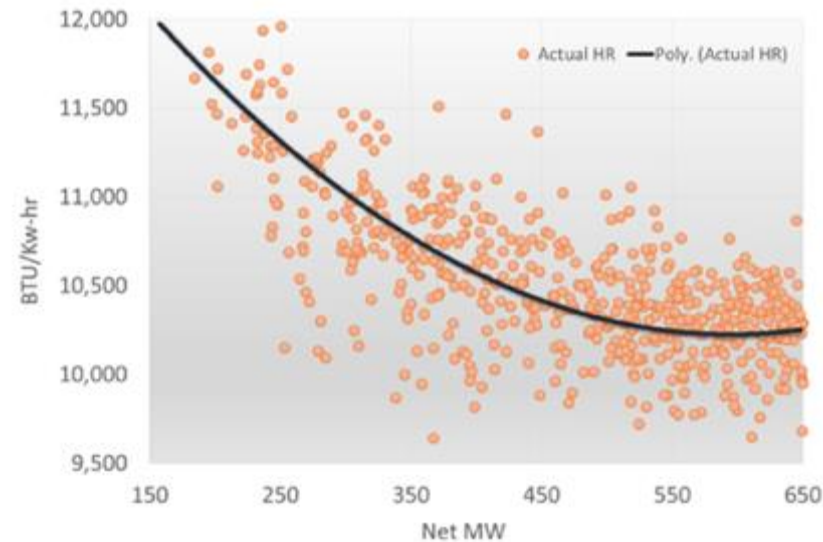
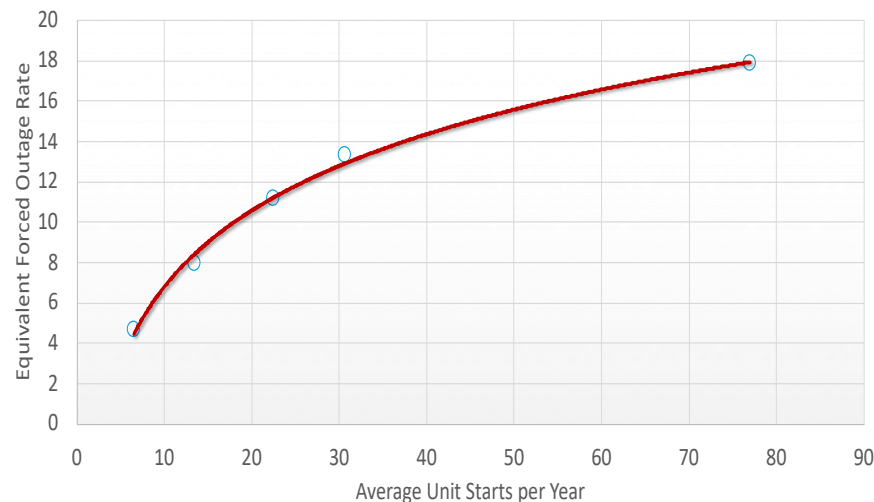
**If you measure it, you can manage it.**

# Flexibility and Heat Rate

Cycling is the least desirable. It consumes component life at the greatest rate\*

- Poses the greatest risk for a plant damaging accident. (Operator error or equipment malfunction)
- Requires the longest period of time for the unit to be available for changing load demand
- Incurs the greatest fuel costs per MW generated

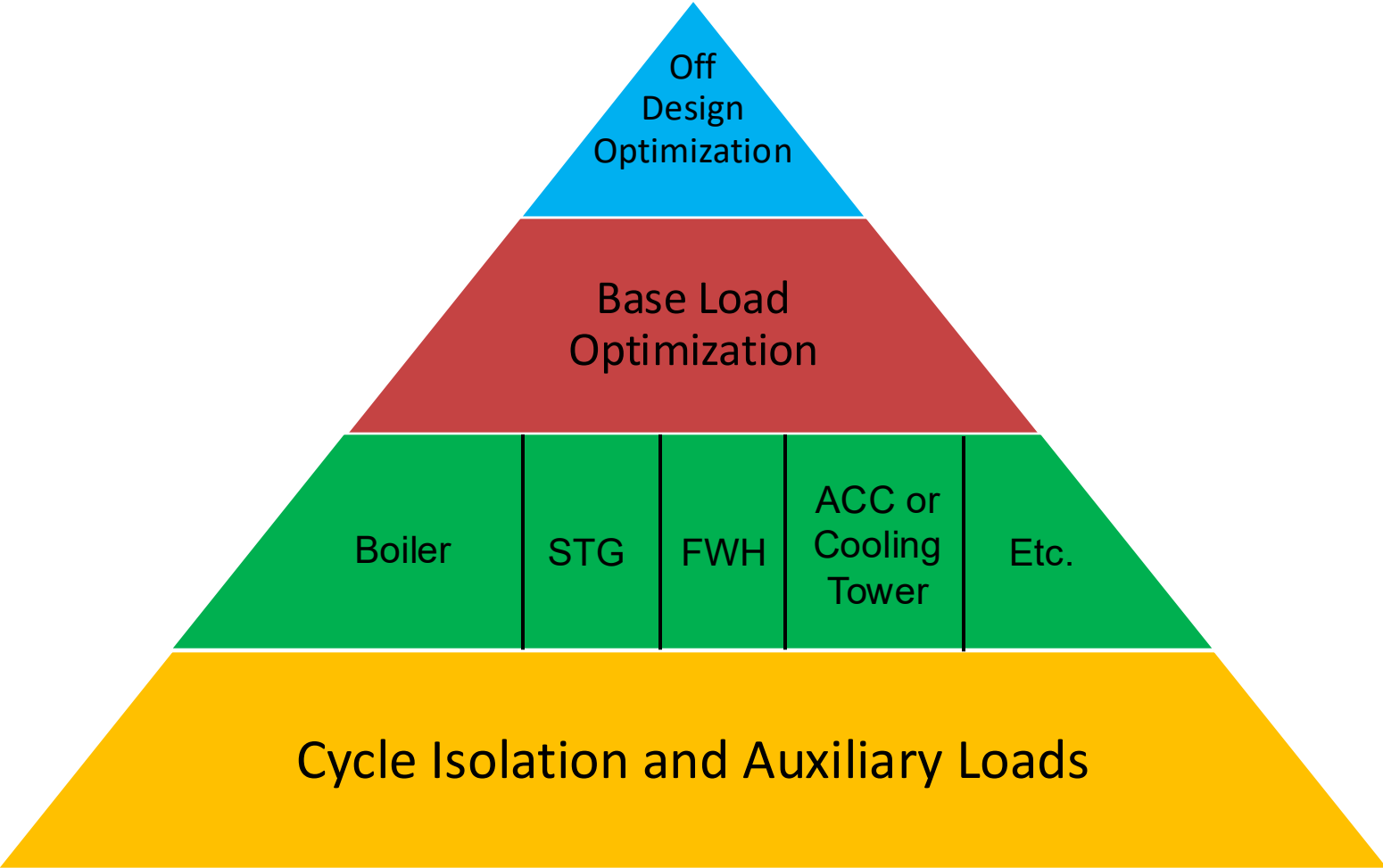
\* *Highly dependent on unit configuration and operator observance of guidelines and operating limits.*



Subcritical Coal Unit Example

# Performance Optimization – Rankine Cycle Units

## *Performance Optimization Pyramid*



# Performance Optimization Pyramid

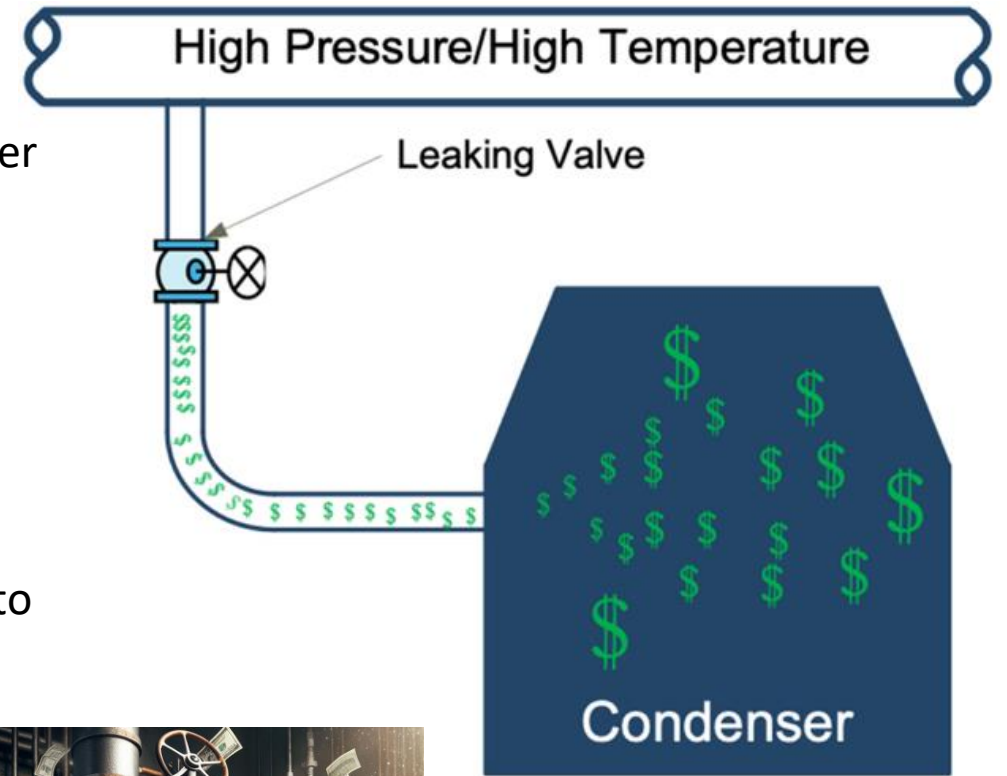
## *The Base*

- **First level of performance is ensuring you are as close to the design performance as possible.**
  - All the steam and water are going where they were designed to go.
    - Heat balances are missing a lot of pipes and drains. The reason is because any piping not shown on the heat balance should have zero flow through it.
  - At base load extra auxiliary loads should be off or out of service potentially on standby.
    - The plant was not designed for them to be in service according to the heat balance diagrams showing the energy users.
- **Once the base “new and clean” condition has been determined and losses have been at least minimized then you can properly evaluate the other components in the power cycle.**

Cycle Isolation and Auxiliary Loads

# Cycle Isolation Assessments

- Cycle isolation is key to evaluating the performance of the entire power cycle or individual components. Cycle isolation provides the basis for evaluating a steam power cycle as it verifies correct cycle alignment and the correct destination for cycle energy.
- Cycle isolation improves the efficiency of your plant, reduces energy and water loss from the steam cycle, and facilitates accurate and repeatable performance tests of the whole power cycle or individual plant components. This is true even when only partially executed.
- Has been successfully been used as a training tool for new engineers to help them learn the power cycle.

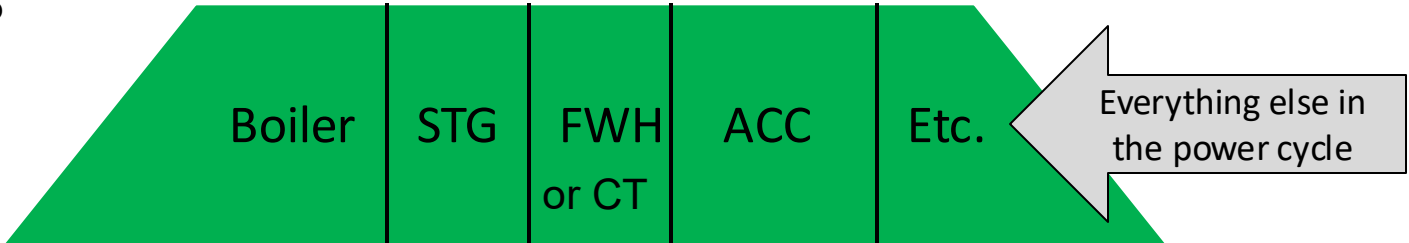


# Performance Optimization Pyramid

## The Power Cycle Components

- Once the Base power cycle has been restored to new and clean and we know where the energy/steam and water are going, we can properly evaluate the components for performance degradation and deficiencies.

<b>Boiler:</b> <ul style="list-style-type: none"><li>Is the fuel consistent?</li><li>Where is the fireball located at base load and part loads?<ul style="list-style-type: none"><li>Combustion Tuning<ul style="list-style-type: none"><li>Where is the air going?</li></ul></li></ul></li><li>Are the Air Preheaters leaking?</li><li>Is the ductwork leaking?</li><li>What burners are in service at what loads?</li></ul>	<b>STG</b> <ul style="list-style-type: none"><li>How do the current sectional efficiencies compare to design or to the last upgrade?</li><li>Do you have erosion problems?</li><li>Have you had blade failure problems?</li><li>Do you have over heating problems</li></ul>	<b>FWH</b> <ul style="list-style-type: none"><li>Are the feedwater heaters meeting their design DCA and TTD's?</li><li>How many plugged tubes do each of your feedwater heaters have?<ul style="list-style-type: none"><li>Do you need to retube or replace any feedwater heaters?</li></ul></li><li>Are your feedwater heaters maintaining levels properly?</li></ul>	<b>ACC or CT</b> <ul style="list-style-type: none"><li>Backpressure limited?</li><li>Do you have air in-leakage problems?</li><li>ACC or Condenser air blanketing<ul style="list-style-type: none"><li>Temperature</li><li>IR Inspections (ACCs)</li></ul></li><li>How are the fans dispatched?</li><li>Do you have fan or gearbox problems?</li><li>Condition of fill on CT<ul style="list-style-type: none"><li>Trending weight?</li></ul></li><li>Status of water treatment</li><li>Plume issues?</li></ul>
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# Performance Optimization Pyramid

## Base Load Optimization

- Is the unit able to consistently run at its design base load capacity and heat rate?
- Are the superheater and reheater sprays operating in accordance with what was predicted in the design heat balances?
- Can you achieve the performance that the unit is dispatched to during all ambient conditions?
  - How often are the dispatch curves updated? Do you have a set process to do this that provides repeatable and achievable results?
- Do your outages improve heat rate and capacity?



Base Load  
Optimization

# Performance Optimization Pyramid

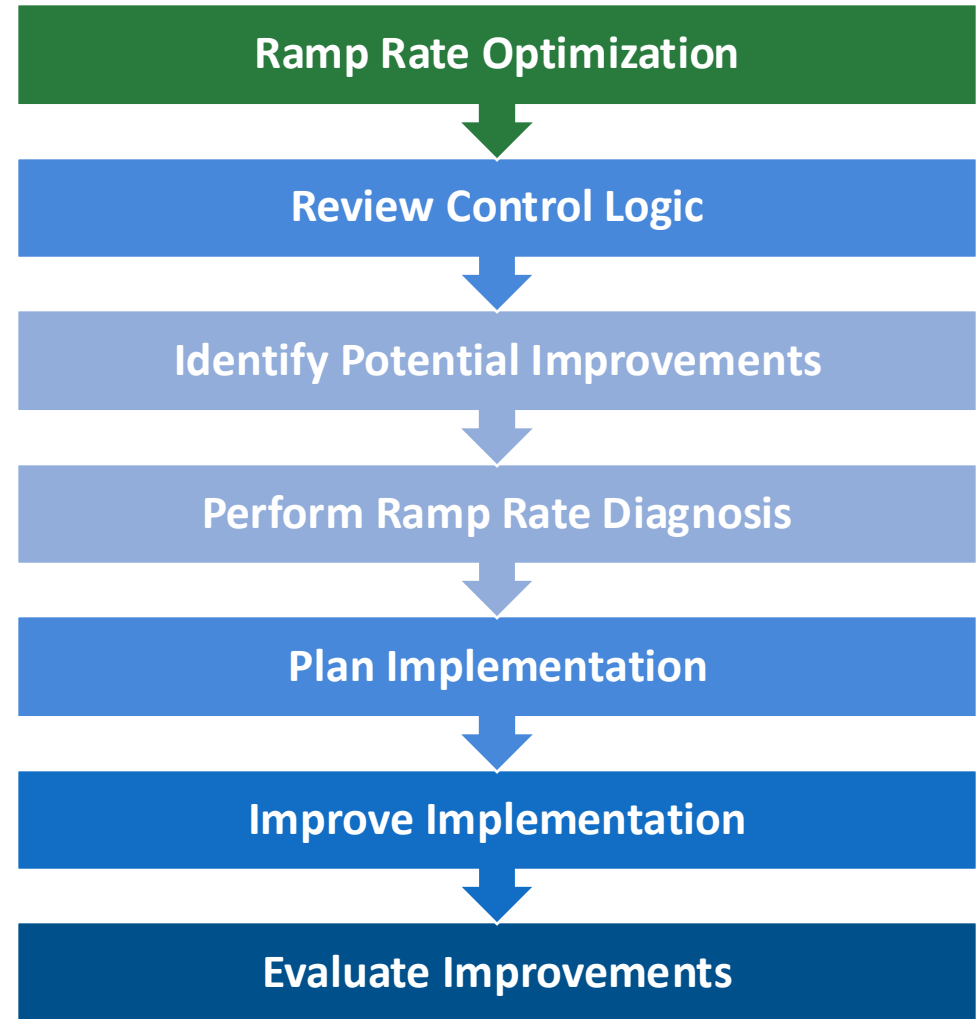
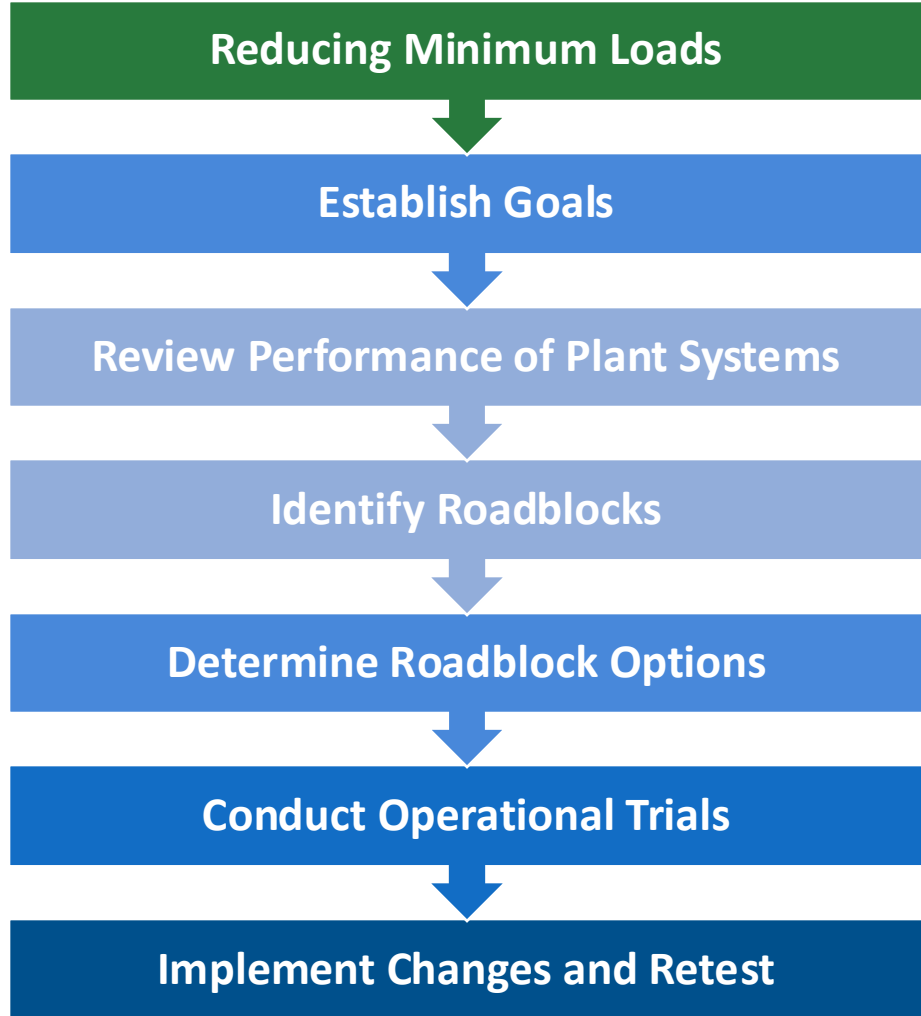
## Off Design Optimization

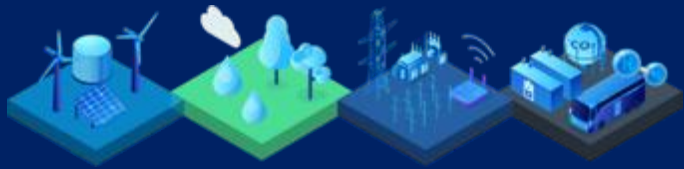
- Startup Optimization
  - Where and when do you change Auxiliary steam sources to the steam turbine driven boiler feedpump?
  - Which burners are in service at which load?
- Ramp Rate Optimization
  - Can we improve your ramp rates?
  - Can we slide pressure down lower to improve efficiency at low load?
  - Can we reduce minimum load?
- Can we increase capacity or reduce heat rate with design improvements?
  - Steam turbine design improvements
  - Boiler design improvements
  - Air Cooled Condenser design improvements
- Will providing Ancillary services improve revenue, plant dispatch, and operations?



Off  
Design  
Optimization

# Systematic Optimization | Performance Preservation





# High-Level Flexibility Assessments

## Project Objective and Scope

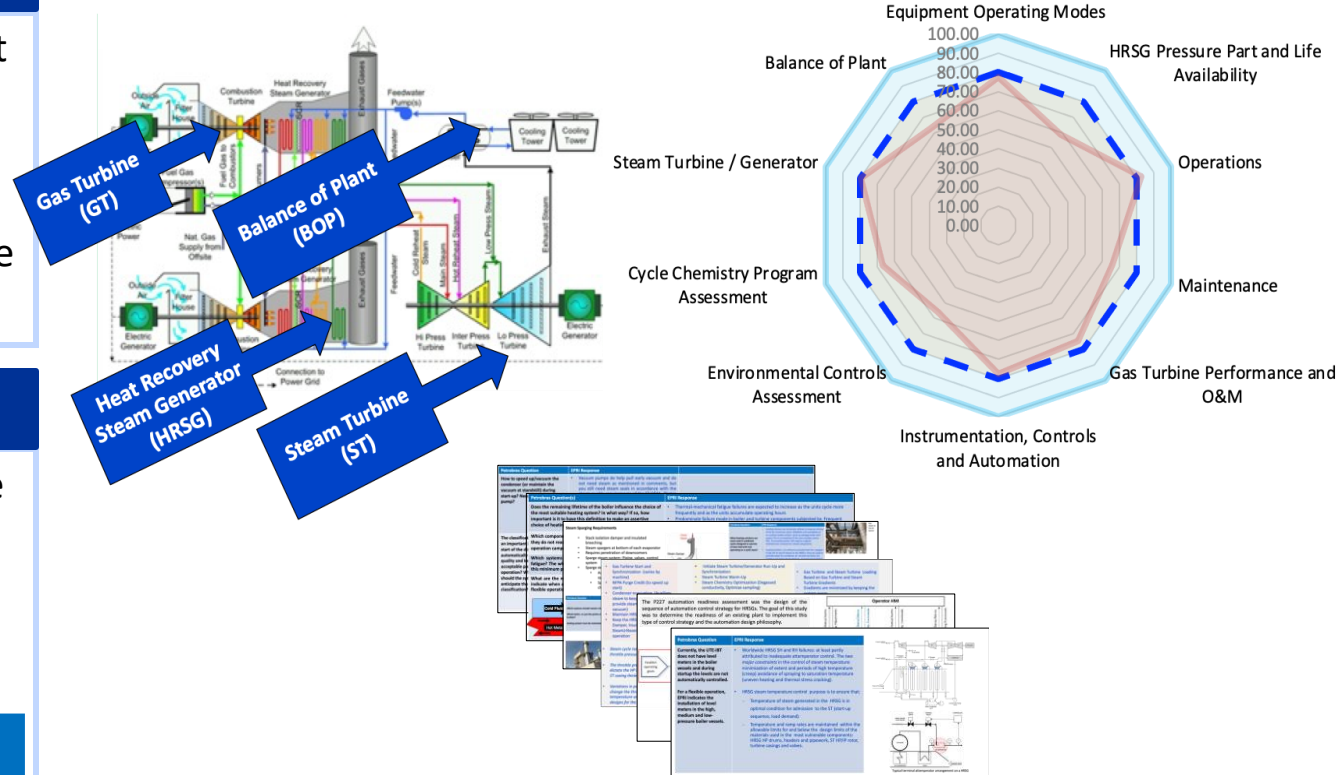
This project's primary goal is technology transfer and assessment support. By establishing an ever-broader collaboration, EPRI can maintain that industry knowledge and learnings from this work may be captured and shared, providing more informed research where gaps may exist and allowing for the opportunity to provide additional industry insights into flexible operations.

## Key Developments and Updates

Supplemental projects can be tailored to include virtual or onsite assessments, training and/or support with managing flexible operations (as needed). This assessment offers an great opportunity to engage with various EPRI programs to identify gaps and areas that need to be addressed for improvements.

### High-Level Assessment Tools:

High-Level Flexibility Assessment Tool: Conventional Steam Generators	300201990
High Level Flexibility Assessment Tool: Combined Cycle Units	3002024227



## Schedule and Upcoming Work

For more details on high-level assessments, contact: Stephen Storm and/or Grant Lanthorn.

# Flexibility Assessments



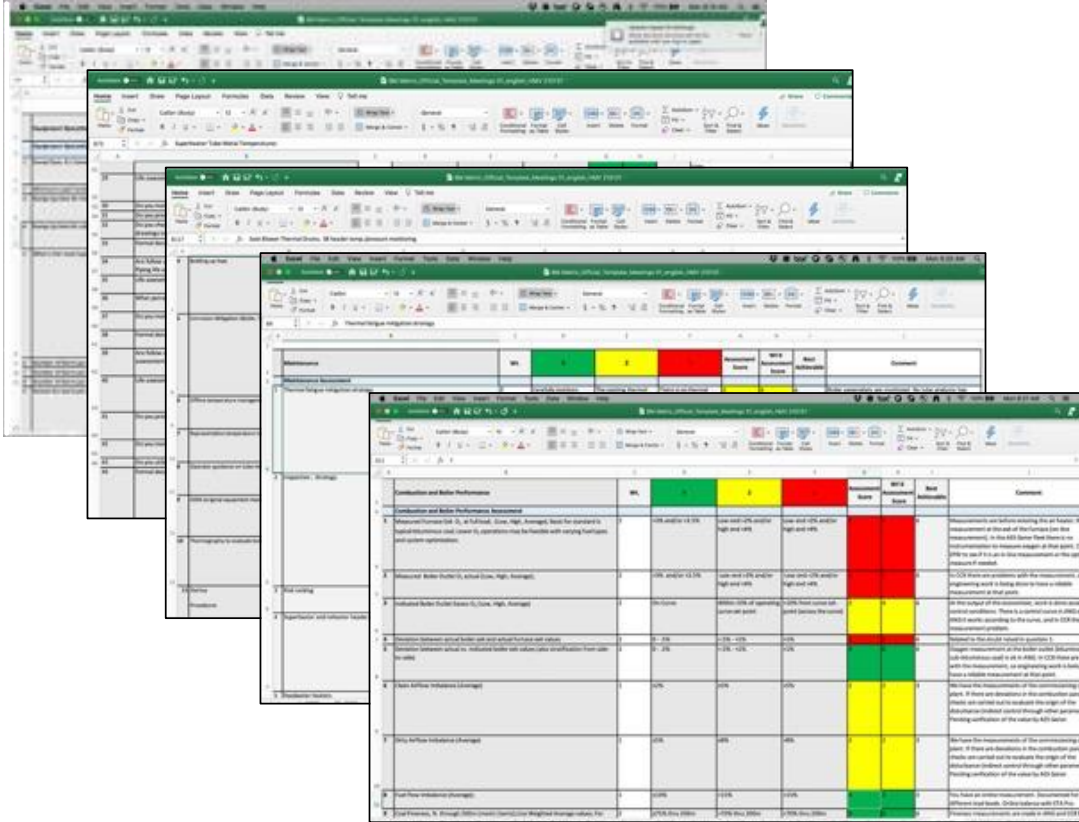
A comprehensive assessment of flexibility should be carried out.



Assessments should cover - major plant systems to identify the gaps and the vulnerable areas for prioritization of the interventions.

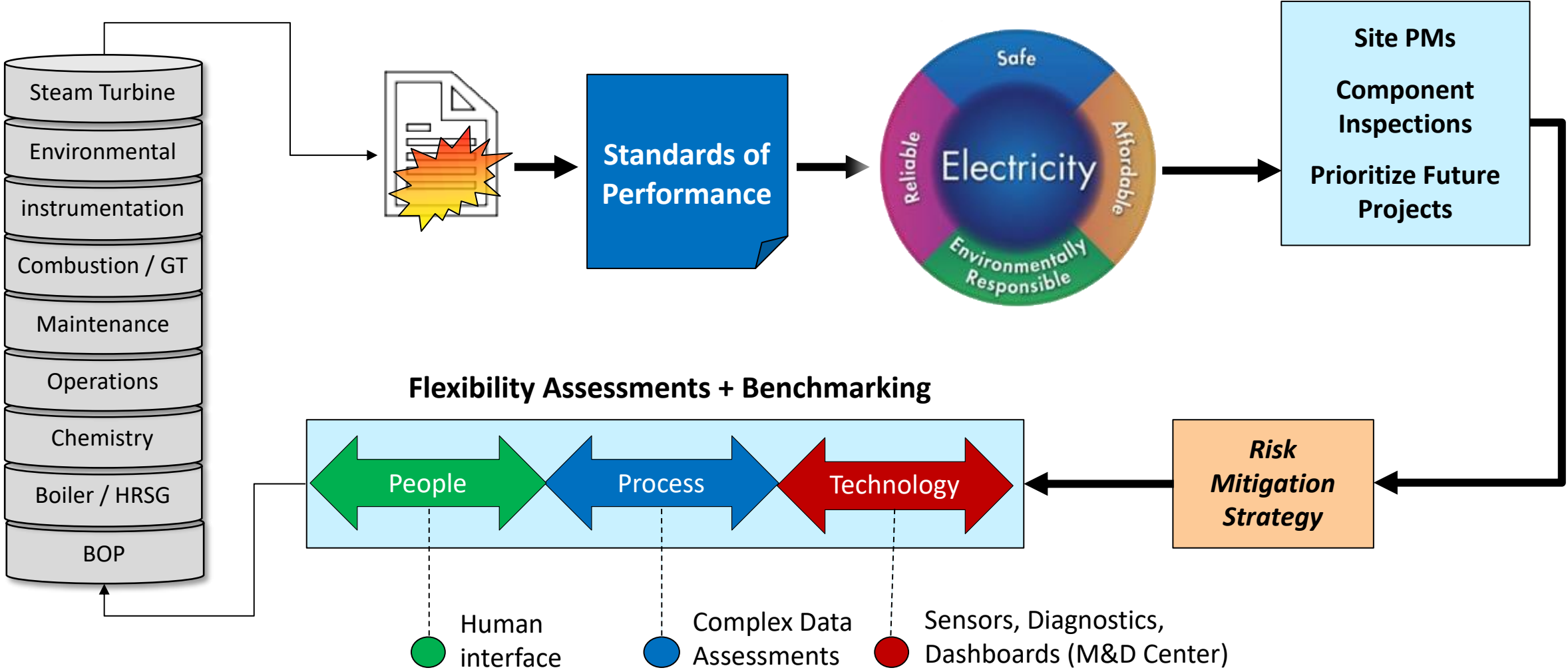


The prioritization of interventions should be based on the operating strategies of the plant – reduction in minimum loads with/without fuel quality variability, reduction of start-up time or reduction of online hours (requiring layup).

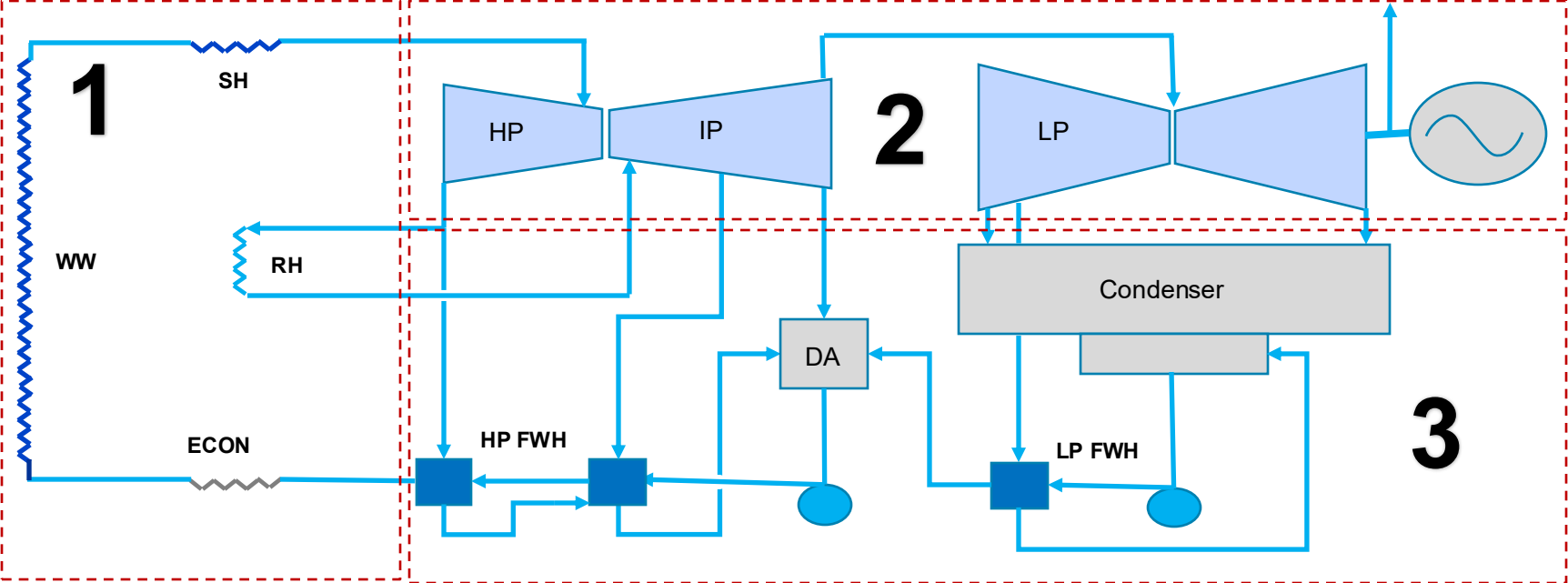


High-Level Assessment Tools:	
High-Level Flexibility Assessment Tool: Conventional Steam Generators	300201990
High Level Flexibility Assessment Tool: Combined Cycle Units	3002024227

# Heat Rate and Flexibility Risk Management Alignment



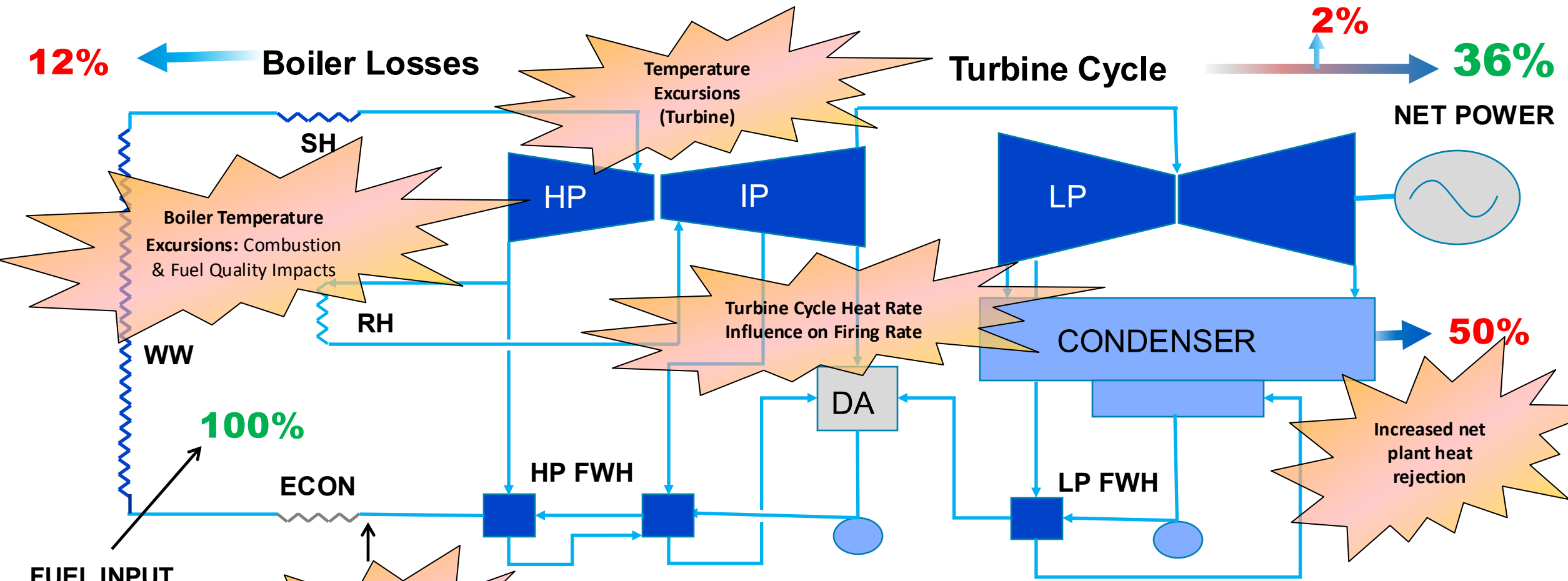
# High-Level Assessment: Conventional Steam Unit



## 4

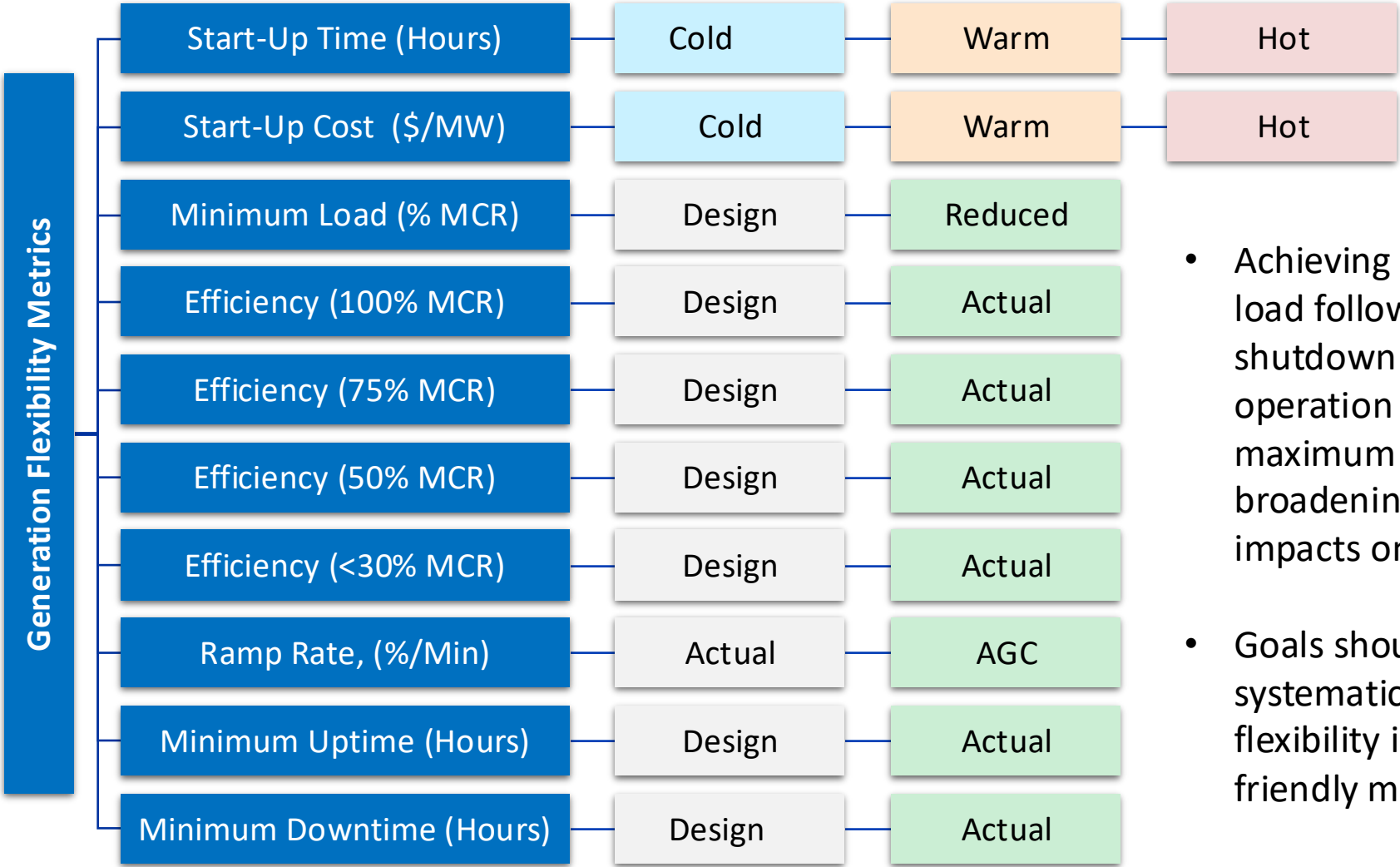
<b>NO<sub>x</sub></b>	LNB	OFA	SNCR	SCR
<b>SO<sub>x</sub></b>	WET FGD	DRY SCRUBBER		
<b>PARTICULATES</b>	ESP	BAGHOUSE		
<b>OTHER VARIABLES IMPACTING ENVIRONMENTAL</b>	CARBON INJECTION	TRONA INJECTION	SLAG MITIGATION CHEMICALS	HYDRATED LIME

# Increased Demand for Dispatchable Generation



- Increasing regional energy mix with non-dispatchable generation decreases the capacity factors of thermal generating assets in the same region.
- This increases the demand for flexibility, fixed cost of generation, increasing wear and tear, resulting with a negative impact on capital and O&M costs.

# Evaluating Demand vs. Capability



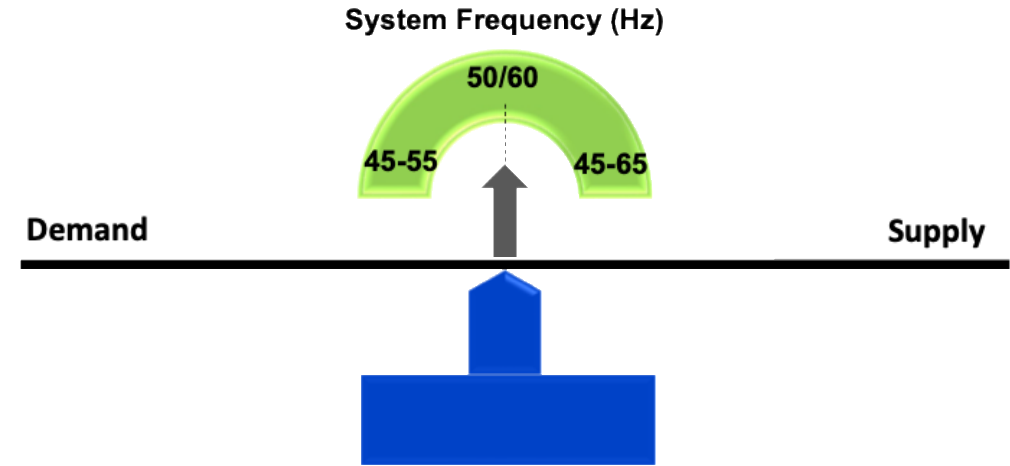
- Achieving flexible operations such as variable load following, faster ramp rates, start-up and shutdown cycling, increased durations of standby operation and being offload, pushing limits of maximum and minimum load and even broadening fuel mix criteria, has complex impacts on plant itself.
- Goals should be established after application of a systematic approach is applied to improve flexibility in a safe, efficient, environmentally friendly manner.

# Equipment Operating Modes

**FLEXIBILITY RISK**

Equipment Operating Mode	WL	1	2	3	Assessment Score	WFL Assessment Score	Best Achievable	Comments
Equipment Operating Mode								
Pump Rate, %/minute	3	0	0	0			0	25% from today, after time in we could reach 2.5%/min (above in other plants with similar unit); document sent by mechanical design
Minimum Load Turndown Capability	3	100	100	100			0	90 MW @ 2.7% min load with frequency control
Pump Up time for Hot Start	3	1 hour	2 hours	4 hours			0	120 min (2.8 hrs) from synchronization to max load, all min (2 hrs) synchronization to min load, start to synchronization 90 mins (2.5 hrs), add reports by RD
Pump Up time for Cold Start	3	2 hours	4 hours	4 hours			0	120 min (2 hrs) from synchronization to max load, 130 min (2.2 hrs) synchronization to min load, start to synchronization 90 mins (2.5 hrs), add reports by RD
What is the most typical operating mode?	3	Standard	Expanded the operation range of a unit's output by lowering the unit's minimum load, 100% remains in service, but load is varied widely. Coming from maximum load to low load, units expected to rapidly change load demand	Cycling on/off, taking the unit in and out of service, (boiling hot, warm, or cold starts)			0	Minimum and maximum load, with CPU
Number of Startups per year (Hot)	3	<10	<10	<10			0	100 Start (1), add design comment section 1.2 manual
Number of Startups per year (Warm)	3	<10	<10	<10			0	100 Start (1), add design comment section 1.2 manual
Number of Startups per year (Cold)	3	<10	<10	<10			0	100 Start (1), add design comment section 1.2 manual
Reason for startups per year inquiry	3						0	Starts are planned (major driven by market demands)
							0	Starts are most often related to reliability issues and not market, fuel or water constraints

1	Ramp Rate Control
2	Reduced Minimum Load
3	Start-ups & shut-down Quality & Consistency
4	Guidance for plant lay-up and/or reserve shut-downs
5	High-level Flexibility metrics and Goals



## Cycling on/off

- Taking the unit in and out of service. (Hot, warm, or cold starts)

## Turndown

- Expanding the operation range of a unit's output by lowering the unit's minimum sustainable load and heat input.

## Fast Ramping

- Units that can keep pace with rapidly changing load demand will be the ones selected for dispatch.

## Load Cycling

- Unit remains in service, but load is varied widely, running from maximum load to low load

# Operations & Maintenance

**FLEXIBILITY RISK**

	WL	3	2	1	Assessment Score	WYD Assessment Score	Best Achievable	Comment
Maintenance								
Maintenance Assessment								
Thermal fatigue mitigation strategy	2	Carefully monitors operating parameters to mitigate thermal fatigue. Overheating occurs, the station will perform an engineering review of the systems and equipment materials affected	The existing thermal fatigue mitigation strategy needs improvement.	There is no thermal fatigue mitigation strategy. Or, minimal monitoring/ actions are taken to mitigate future temperature excursions.	2	4	6	Boiler parameters are monitored. No tube analysis has been done.
Inspection Strategy	2	Parameters and procedures are periodically evaluated and adhered to for improved plant operations and forward planning for replacement of critical components; Frequency of inspections is optimized and aligned with engineering	An inspection strategy exists but needs improvement; Frequency and quality of major component inspections in not aligned with engineering.	No inspection Strategy exists; Inspection parameters, procedures and teams need guidance and direction	3	5	6	There is an annual monitoring plan.
Risk ranking	2	Risk Ranking utilized to prioritize projects	Sometimes Risk Ranking is utilized; Needs improvement	Not applicable	3	4	6	A risk assessment is made of the equipment; maintenance plans are based on this assessment. (ISO 50001 certification)
Superheater and reheater header program	2	Station monitors temperatures, follow operating procedures, and periodically inspects all headers; Ensures that all thermocouples are installed and in good working order.	The inspection and monitoring program needs improvement	Monitoring is not representative, and the inspection program is inadequate and/or doesn't exist.	2	4	6	The work is done and the instrumentation is in good condition. An external inspection of the headers is made. Investigation of the type of inspection for this type of headers.

**FLEXIBILITY RISK**

	WL	3	2	1	Assessment Score	WYD Assessment Score	Best Achievable	Comment
Maintenance								
Maintenance Assessment								
Thermal fatigue mitigation strategy	2	Carefully monitors operating parameters to mitigate thermal fatigue. Overheating occurs, the station will perform an engineering review of the systems and equipment materials affected	The existing thermal fatigue mitigation strategy needs improvement.	There is no thermal fatigue mitigation strategy. Or, minimal monitoring/ actions are taken to mitigate future temperature excursions.	2	4	6	Boiler parameters are monitored. No tube analysis has been done.
Inspection Strategy	2	Parameters and procedures are periodically evaluated and adhered to for improved plant operations and forward planning for replacement of critical components; Frequency of inspections is optimized and aligned with engineering	An inspection strategy exists but needs improvement; Frequency and quality of major component inspections in not aligned with engineering.	No inspection Strategy exists; Inspection parameters, procedures and teams need guidance and direction	3	5	6	There is an annual monitoring plan.
Risk ranking	2	Risk Ranking utilized to prioritize projects	Sometimes Risk Ranking is utilized; Needs improvement	Not applicable	3	4	6	A risk assessment is made of the equipment; maintenance plans are based on this assessment. (ISO 50001 certification)
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8	Equipment Preservation
9	Mill Performance at Minimum Loads
10	Preventative Maintenance on Igniters and Flame Scanners
11	Operational Procedures vs. Automation Needs
12	Low Load temperature control
13	O <sub>2</sub> and CO measurements, Representation and control
14	SCR performance; Fouling; Gas Flow (and dew-point) Impact

15	Boiler, Piping and FAC Inspections
16	Forecasting Modes of Operations to plan Spare Part Inventory
17	Monitoring Instrumentation and Sensors; Processes for Mitigating Failure Mechanisms
18	Equipment Reliability at Start-up

# Boiler Life and Combustion Performance

**FLEXIBILITY RISK**

Question	Yes	No	Score	Comments
Life assessment program for all high energy piping (including steam and elbows)?	Yes	No	3	EPRI. The programs are in place and are starting to run. Doubt about the concept of "life assessment" - current status at "where you are" in the life cycle. Consult EPRI.
Do you monitor temperature for MS (main steam) & RH (reheat) piping?	Yes	No	2	Yes, it is monitored online.
Do you predict life for every pipe weld or weld joint on High Energy Piping (HEP)?	Yes	No	2	Yes.
Do you check all HEP (high energy piping) components for long term welds even if drawings indicate the component is seamless?	Yes	No	1	Yes, due to the with age (2 and 10 years).
Formal documentation of HEP (high energy piping) inspection & analysis results	Yes	No	2	Yes, because we are in the preparation stage of this process.
Are follow up actions (based on inspections/analysis results) part of your High Energy Piping Life assessment program?	Yes	No	2	Yes, because we are in the preparation stage of this process.
Life assessment program in place for all high temperature headers?	-60%	40-80%	-60	Life assessment program soon to be carried out in ANS, not yet in CCR.
What percentage of headers have been inspected for ligament Damage?	-60%	40-80%	-60	Life assessment program soon to be carried out in ANS, not yet in CCR.
Do you monitor temperature for every header at multiple locations along its length?	Yes	No	2	There is temperature monitoring and it is supervised, according to the points indicated by the manufacturer.
Formal documentation of inspection & analysis results?	Yes	No	2	Yes, the analysis is carried out through the monitoring tool (TA-PR).
Are follow up actions (based on inspections/analysis results) part of your header life assessment program?	Yes	No	1	If there is any indication from TA-PR, action is taken during the outages. In addition, a visual inspection of the headers is made.
Life assessment program for all drums?	Yes	No	2	There is a maintenance program that is used during the outages based on inspection and non-destructive testing. The done, headwater tank, desuperator, among others, are checked.
Do you predict life for all economizer components?	Yes	No	2	There is inspection of the entire economizer. It is reviewed, non-destructive testing is done. No prediction of remaining life is made. Consult with EPRI.
Do you monitor through-wall temperature gradients for economizer?	Yes	No	2	It has online measurement of water temperature at the entrance and exit of the economizer. Consult EPRI.
Do you utilize low flow control valves on headerwater lines?	Yes	No	2	Yes.
Formal documentation of inspection & analysis results?	Yes	No	2	All major components should have a detailed documentation and analysis for understanding its condition and life.

6	<b>Boiler Life and Availability Program</b>
7	<b>Boiler Temperature Protection</b>

**FLEXIBILITY RISK**

Metric	Yes	No	Score	Comments
Combustion and Boiler Performance Assessment	Yes	No	6	Measurements are before entering the air heater, if measurement at the exit of the furnace (see line measurements). In the old burner there there is no instrumentation to measure oxygen at that point. C-EPRI to see if it is in line measurement or the opt measure if needed.
Measured Furnace Exit O <sub>2</sub> at full load; (Low, High, Average); Basis for standard is typical bituminous coal; Lower O <sub>2</sub> operations may be feasible with varying fuel types and system optimization.	+1% and/or +3.3%	Low and +2% and/or high and +4%	Low and +2% and/or high and +4%	
Measured Boiler Outlet O <sub>2</sub> actual (Low, High, Average)	+1% and/or +3.3%	Low and +2% and/or high and +4%	Low and +2% and/or high and +4%	In CCR there are problems with the measurement, engineering work is being done to have a reliable measurement at that point.
Indicated Boiler Outlet Excess O <sub>2</sub> (Low, High, Average)	On Curve	Within 10% of operating curve set point	+10% from curve set point (across the curve)	At the output of the economizer, work is done and control conditions. There is a control curve in ANS. ANS works according to the curve, and in CCR the measurement problem.
Deviation between actual boiler exit and actual furnace exit values	+5% - +1%	+1%	+1%	Related to the doubt raised in question 1.
Deviation between actual vs. indicated boiler exit values (also stratification from side-to-side)	+3% - +1%	+1%	+1%	Oxygen measurement at the boiler outlet (burning sub-bituminous coal) is not in ANS. In CCR there are with the measurement, so engineering work is being done to have a reliable measurement at that point.
Lean Airflow Imbalance (Average)	+2%	+5%	+5%	We have the measurements of the commissioning plant. If there are deviations in the commissioning plant checks are carried out to evaluate the origin of the disturbance (direct control through other parameters) Pending verification of the value by AES-Denar.
Very Airflow Imbalance (Average)	+10%	+8%	+8%	We have the measurements of the commissioning plant. If there are deviations in the commissioning plant checks are carried out to evaluate the origin of the disturbance (direct control through other parameters) Pending verification of the value by AES-Denar.

18	<b>Oil Igniter Reliability</b>
19	<b>Gas Ignition and/or Gas Co-Firing from 0-50% MCR</b>
20	<b>Combustion Optimization</b>
21	<b>Boiler Cleaning Systems Performance</b>
22	<b>Thermal Performance Modeling</b>

# Instrumentation and Environmental Controls

**FLEXIBILITY RISK**

**FLEXIBILITY RISK**

23	Air, Gas, Water, Steam and Environmental System Automation/Control
24	Environmental Controls DCS related
25	Circulating Dry Scrubber (CDS)
26	Boiler Circulation Control
27	Systematic Assessment of Controls

28	Environmental permit limits under Flexible Operations
29	Scrubber Performance
30	APC Systems Layup
31	Ash Build-up (and clean out)
32	ID Fan capacity
33	SCR performance optimization

# Cycle chemistry, Steam Turbine-Generator

**FLEXIBILITY RISK**

**FLEXIBILITY RISK**

34	Cycle Chemistry Guidance
35	Cycle Chemistry Alarms
36	Chemical Cleaning Guidance
37	FAC Program for management and prediction
38	Iron Monitoring
39	Corrosion / FAC (flow-accelerated corrosion) in feedwater pipes: Percent susceptible that have been inspected
40	Condensate Polishers

41	Valve Throttling; Steam Valve functional checks
42	Steam Turbine Generator: Alarm Management
43	Steam Turbine Layout

# Identify Top Roadblocks and Challenges

TEMPLATE	ROADBLOCKS	DESCRIPTION	PRIORITY	DEPT.	ACTION PLAN
(6) INSTRUMENTATION, CONTROLS AND AUTOMATION					
(7) ENVIRONMENTAL CONTROLS	(1) EQUIPMENT OPERATING MODES				
(8) CYCLE CHEMISTRY	(2) PRESSURE PARTS				
(9) TURBINE GENERATOR	(3) OPERATIONS				
(10) BALANCE OF PLANT	(4) MAINTENANCE				
	(5) COMBUSTION AND BOILER PERFORMANCE				

Applying the Systematic Approach

# Identifying Key Opportunity Areas for Improvement

Performance: Heat Rate and Flexibility Program establishment

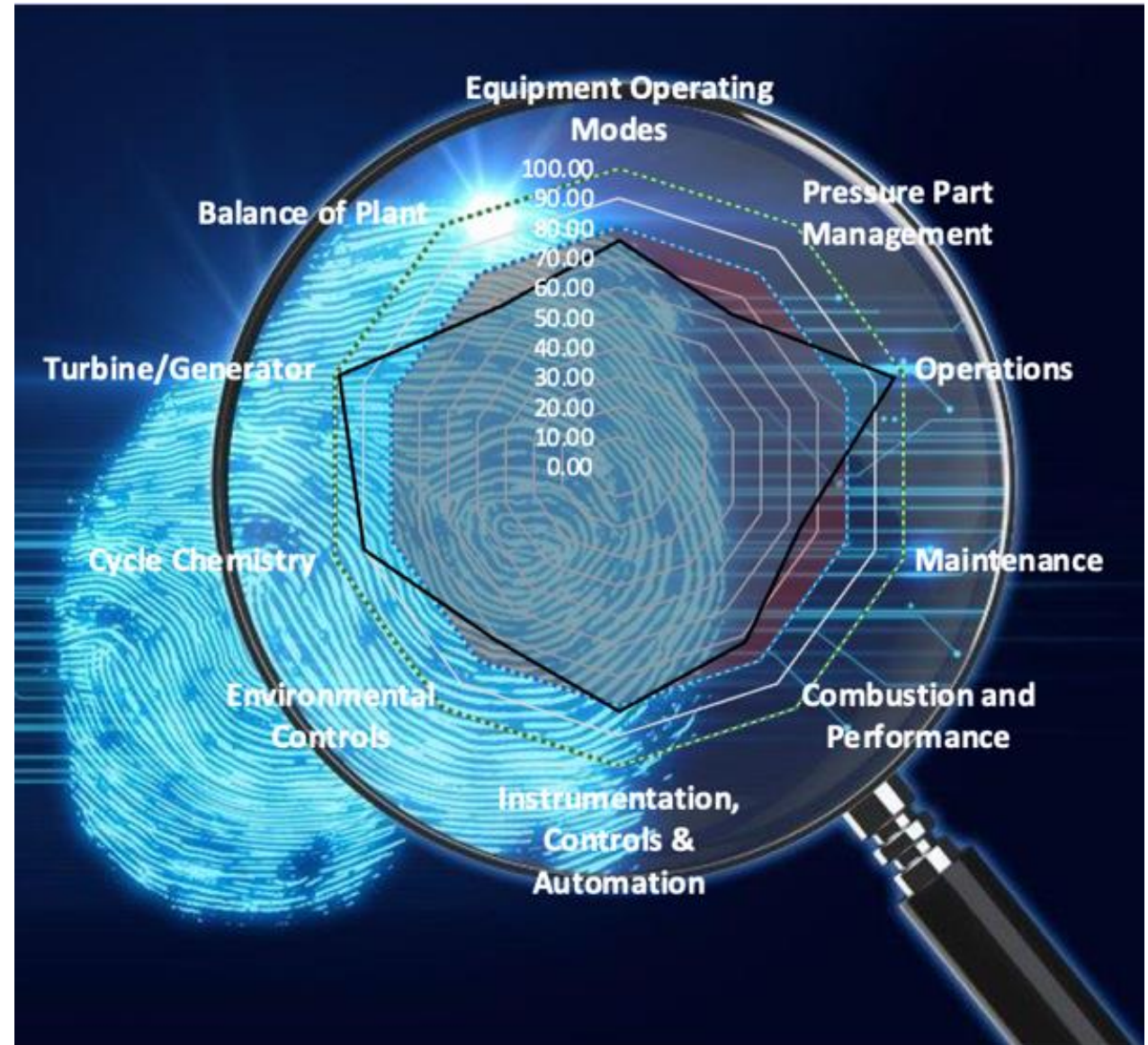
Integrate a Boiler or HRSG Tube Failure Program

Cycle Chemistry Program Management

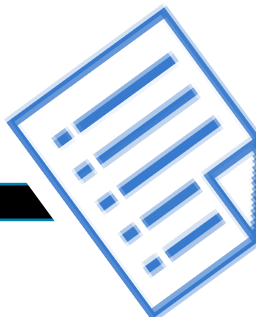
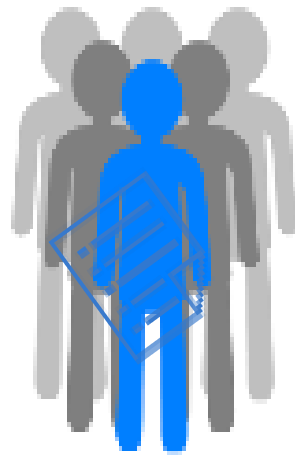
Integrated Asset Management

Steam Turbine Program Management

Generator Program Management



# Program Management



## Program Management

- Quantitative Actions
- Qualitative Actions

## Station Assessments

- Gap identification

## Performance Evaluations

- Flexibility
- Capability
- Efficiency

## Awareness Communication

- Reporting
- Training
- Workshops

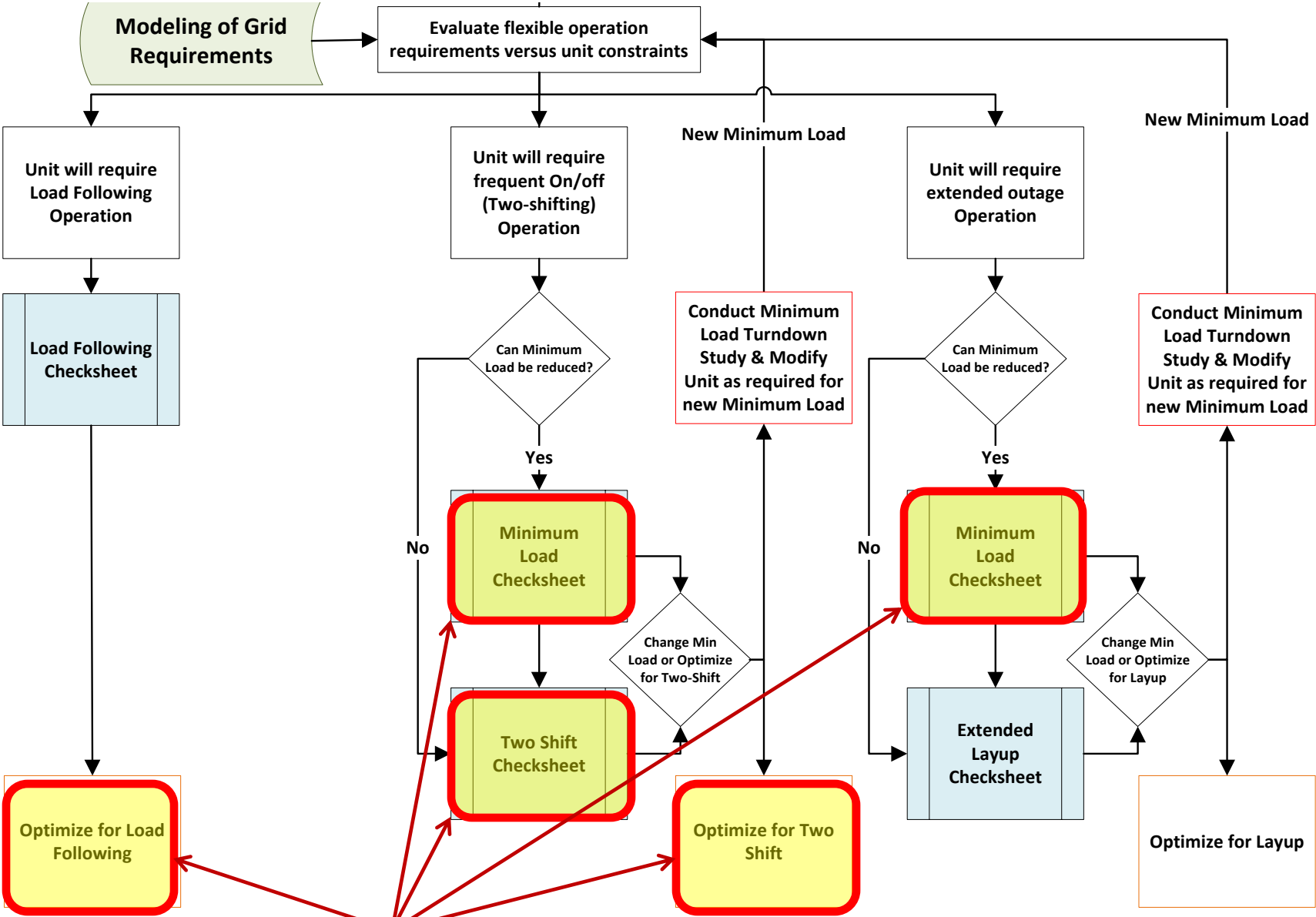
## Recommendations

- Project Development
- Economic justification

**Communicate – Communicate - Communicate**

# Optimization

Once unit goals are established plant system performance reviews are often required to identify roadblocks, challenges, and solutions. These often require operational trials, system improvements, and then retests to validate unit capability.

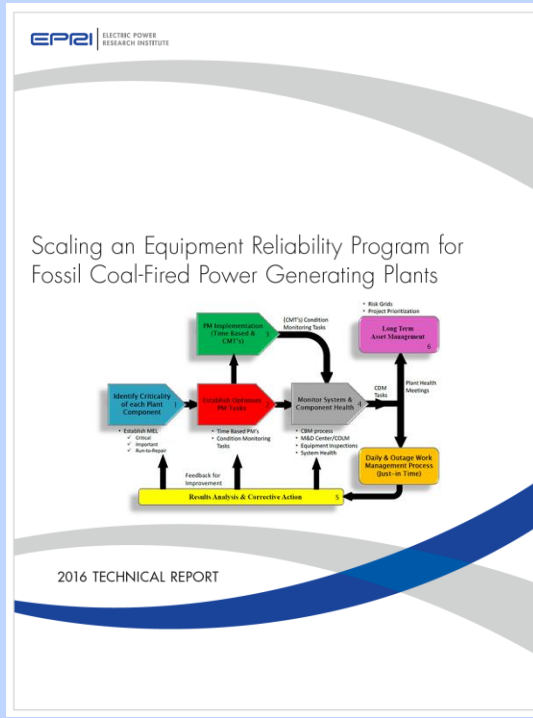
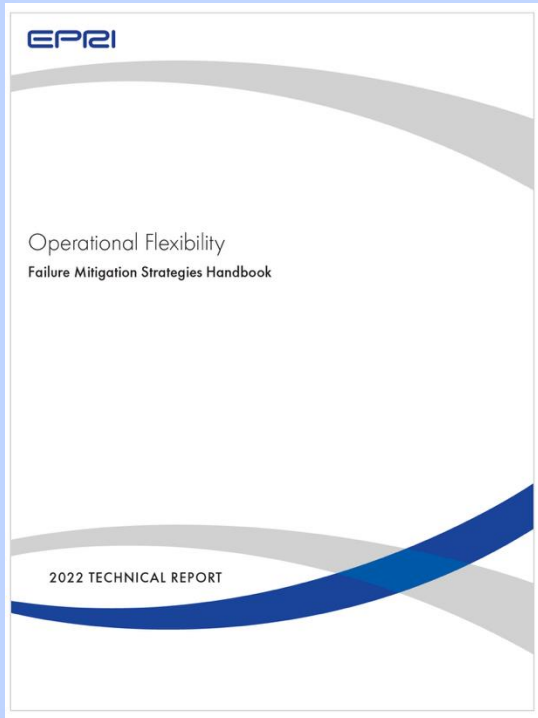


Mode of Operation
Load Following
Minimum Load
Two Shifting

**Performance Plays a Key Role in Optimization**

# Mitigating Flexibility-Driven Failures

- Leveraging mature equipment reliability programs to mitigate failures, target critical equipment, and manage technical and commercial risk



## ER Element 1—Scoping and Identifying System and Component Criticality

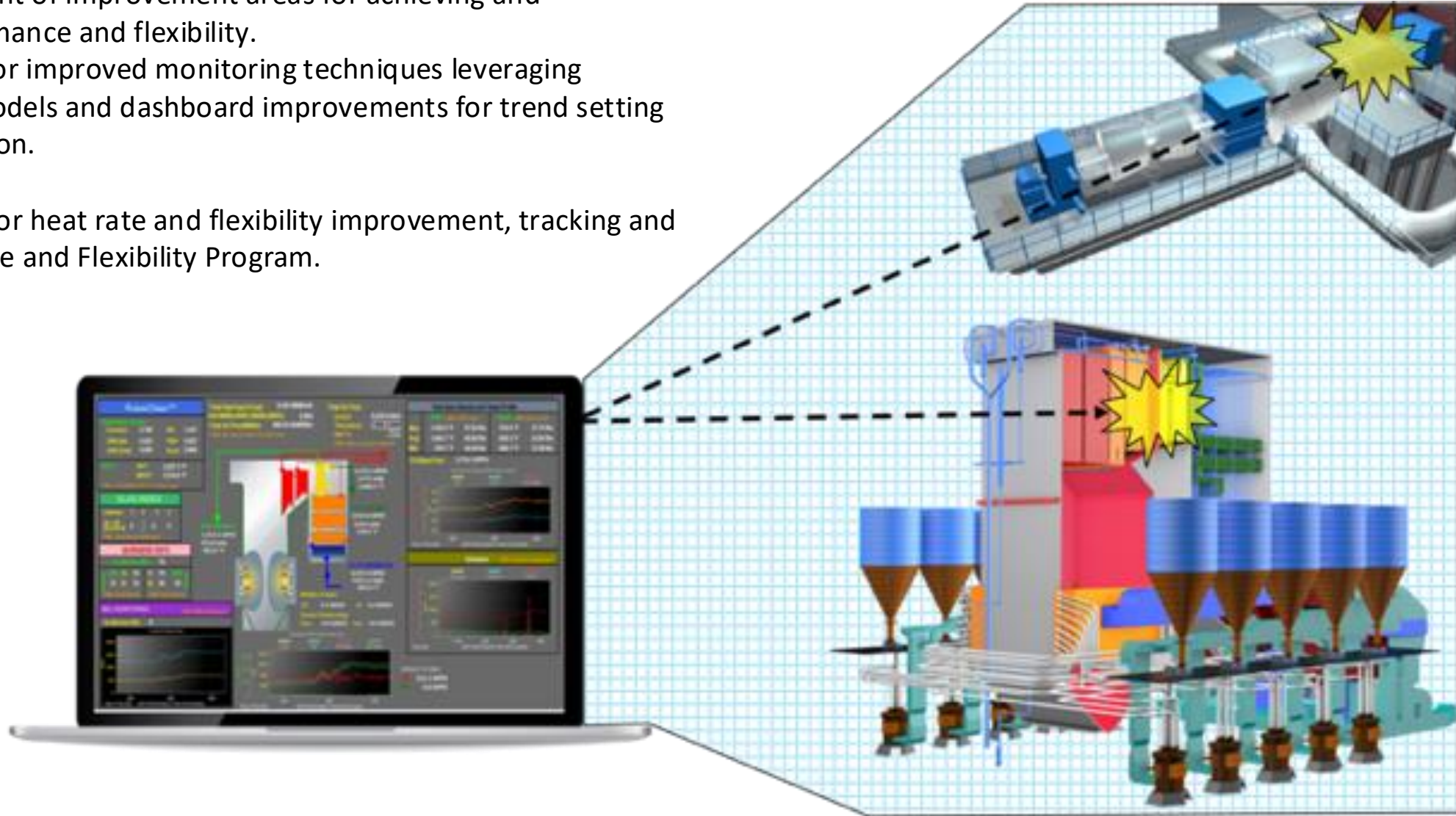
#	ER Sub-Process Element	Considerations	Adjustments/Scaling for Flex Ops	Additional Glidepath Considerations
1.3	Asset criticality	Align criticality rankings to scale program to available resources	<ul style="list-style-type: none"> <li>Similar to important components, RTM components should be identified to allow an organization to identify and eliminate low-value maintenance tasks.</li> <li>Assigning detailed asset criticality rankings (ACRs) can be used to support risk management process.</li> </ul>	<ul style="list-style-type: none"> <li>Consider re-evaluating critical components based on risk tolerance on glidepath.</li> <li>Maintain focus on safety and environmental compliance</li> <li>Apply a commercial availability metric versus loss-of-generation to account for flexible operation.</li> <li>May choose to designate more equipment as RTM but implement mitigation strategies to reduce downtime.</li> </ul>

		Safety	Envr.	Cost	Lost MW's	Efficiency	OCR	SCR	ACR
DXX-1A	1A Circ Water Pump	1	1	6	5	8	11.27	9.11	102.67
DXX-1B	1B Circ Water Pump	1	1	6	5	8	11.27	9.11	102.67



# Performance and Monitoring Assessments

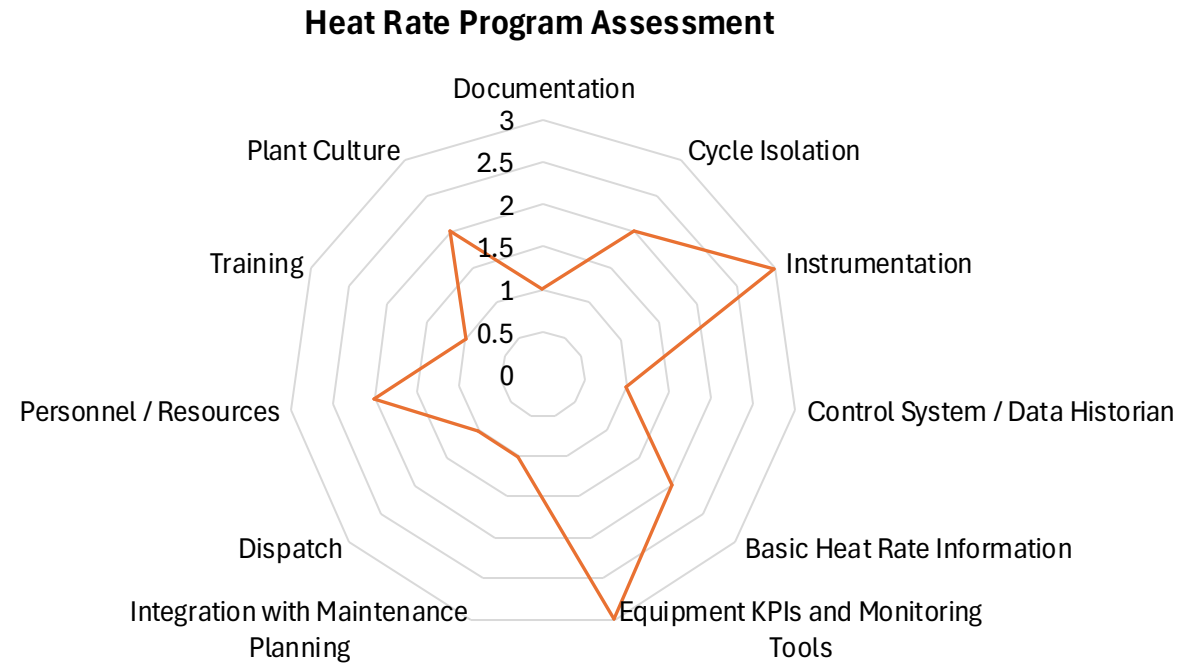
- Alignment and assessment of improvement areas for achieving and monitoring plant performance and flexibility.
- Evaluate opportunities for improved monitoring techniques leveraging thermal performance models and dashboard improvements for trend setting and reporting optimization.
- Identify M&D concepts for heat rate and flexibility improvement, tracking and integration to a Heat Rate and Flexibility Program.



# Applying Results

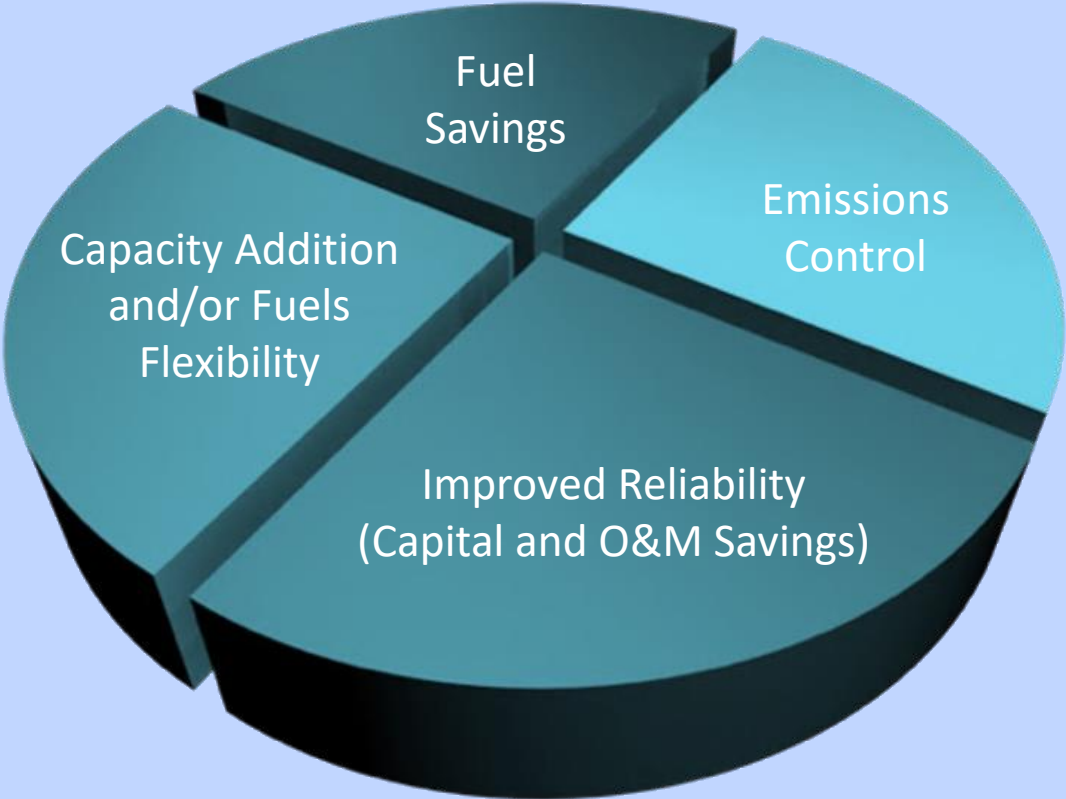
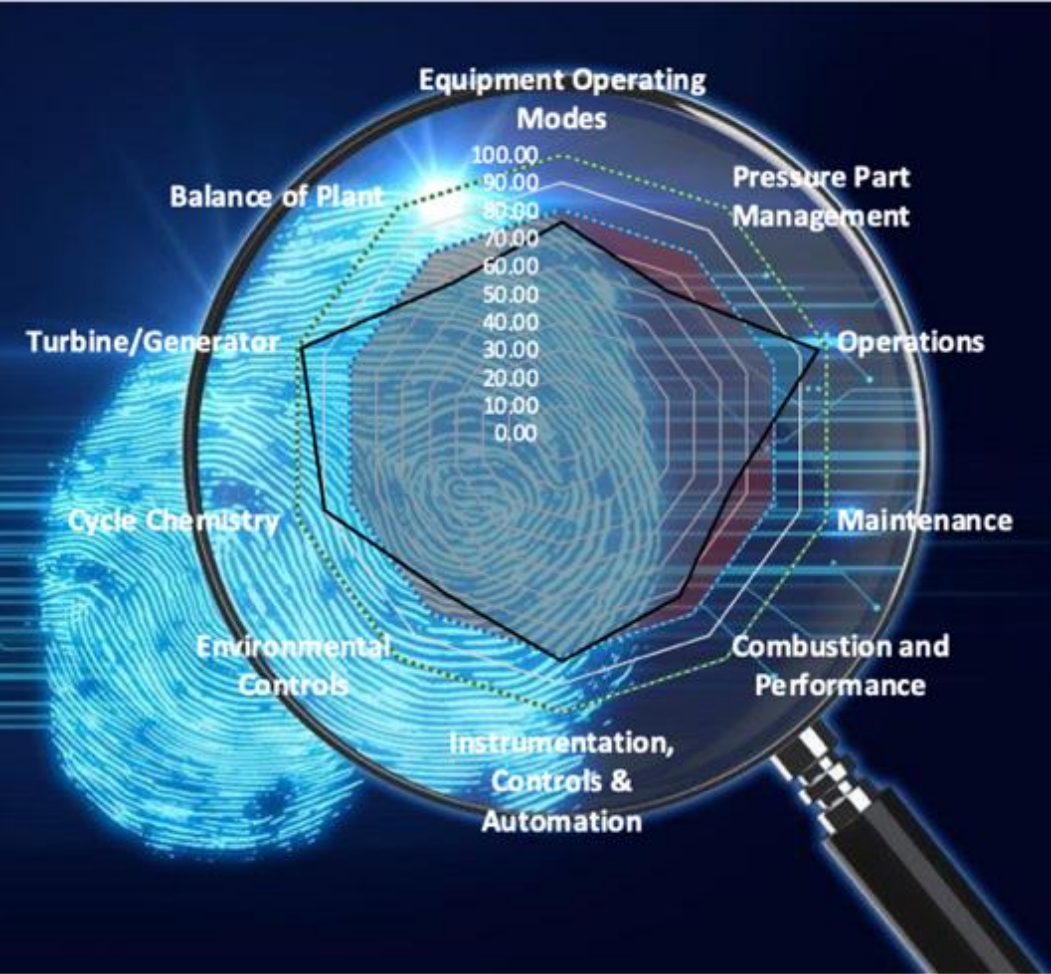
## Heat Rate Program:

- Documentation
- Cycle Isolation
- Instrumentation
- Controls System, Data Historian
- Basic Heat Rate Information
- KPIs & monitoring
- Integration with Maintenance Planning
- Dispatch
- Resources
- Training
- Culture

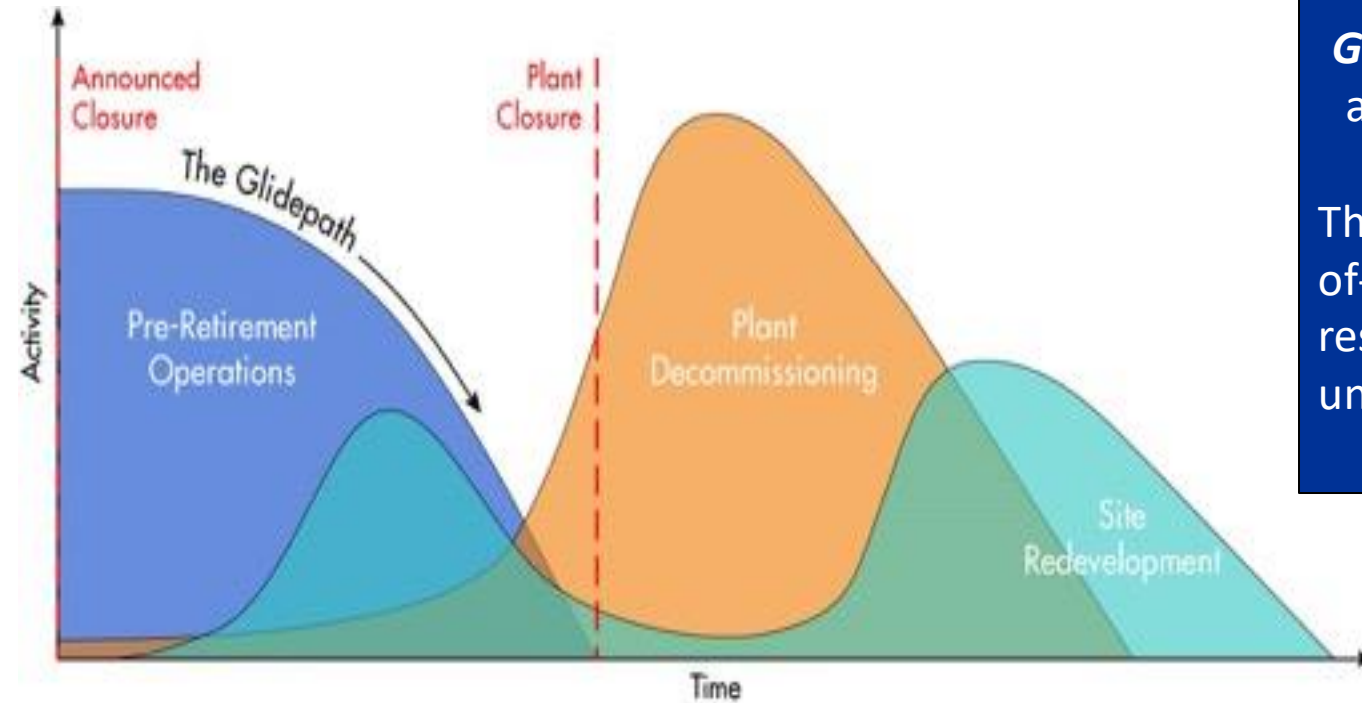


Heat Rate - Conventional Plant	Weight	3	2	1	Score	Best Achievable	Comment
<b>Documentation</b>					1.5	0	
Operating procedures		Detailed site specific operating procedures for all plant equipment.	Have operating procedures for major equipment but limited procedures for minor systems.	Few site specific operating procedures.	1	0	

# “A problem identified is a problem half solved”



# Glidepath Management

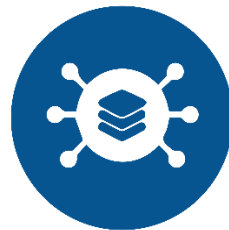


**Glidepath** is the period between the committed retirement announcement through the end of commercial operation.

This implies a “**soft landing**” transition and exit at plant end-of-life, however, plant staff is challenged with increasing resource constraints and flexible operations, complicating unit operation as it nears retirement.



Ensure safe, reliable, viable operation through glidepath period



Determine most effective deployment/highest ROI of limited resources



Tail-risk identification and mitigation

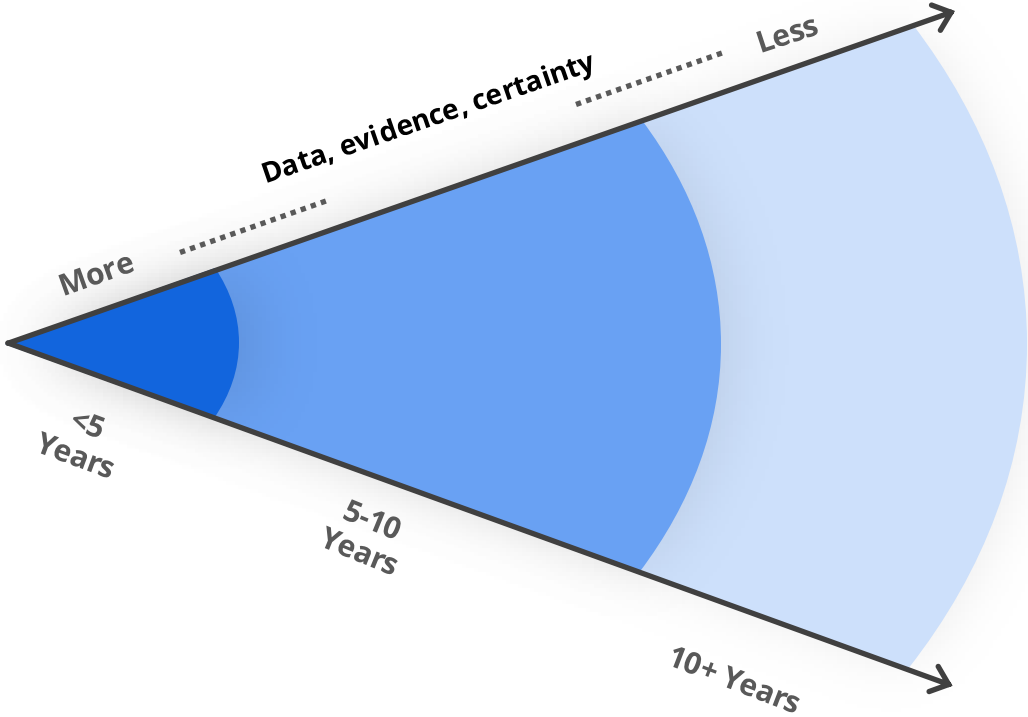
***Optimized Performance & Flexibility Strategy for Glidepath***

# Informing Risk-Management Process

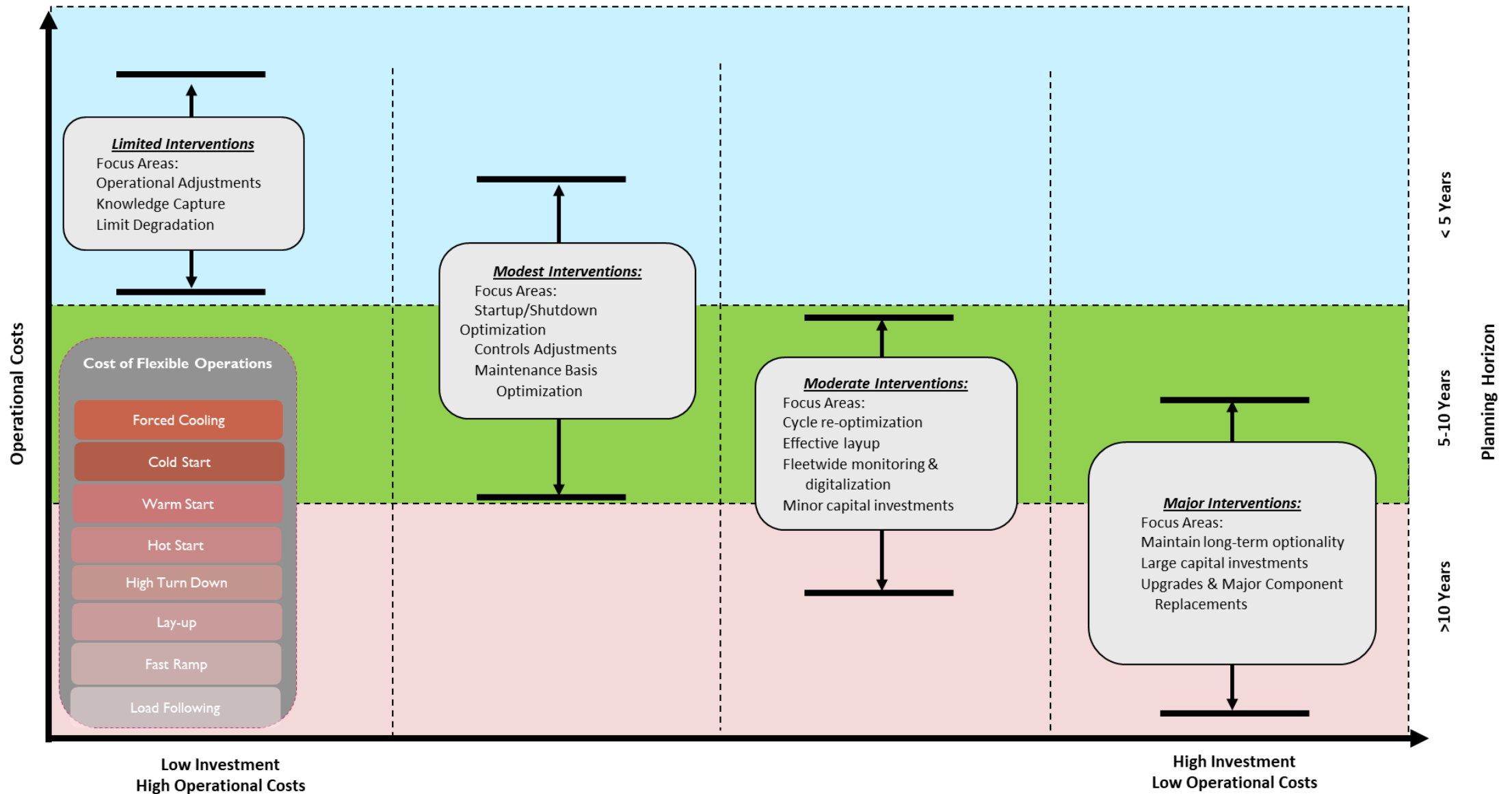


## Scenario Development

Planning Horizon	Operating Mode	Configuration
<5 years	Load Following	Subcritical
5-10 years	On/Off Cycling	Supercritical
10+ years	Layup	



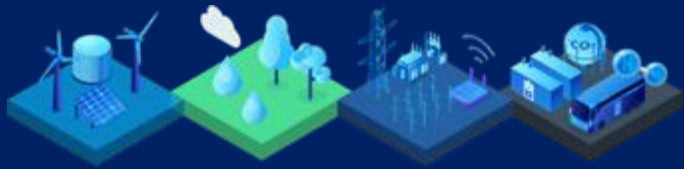
# Managing Glidepath Performance and Flexibility



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**Examples of Recent R&D Activities**  
(time permitting)



# Developing Consistent Heat Input Curves for More Accurate Dispatch

## Project Objective and Scope

The increase in renewable energy injecting into the market has increased the need for unit flexibility. The accuracy of the data provided to dispatch greatly affects the profitability of power plants. Therefore, dispatch curves that accurately reflect the capability of the plant are required.

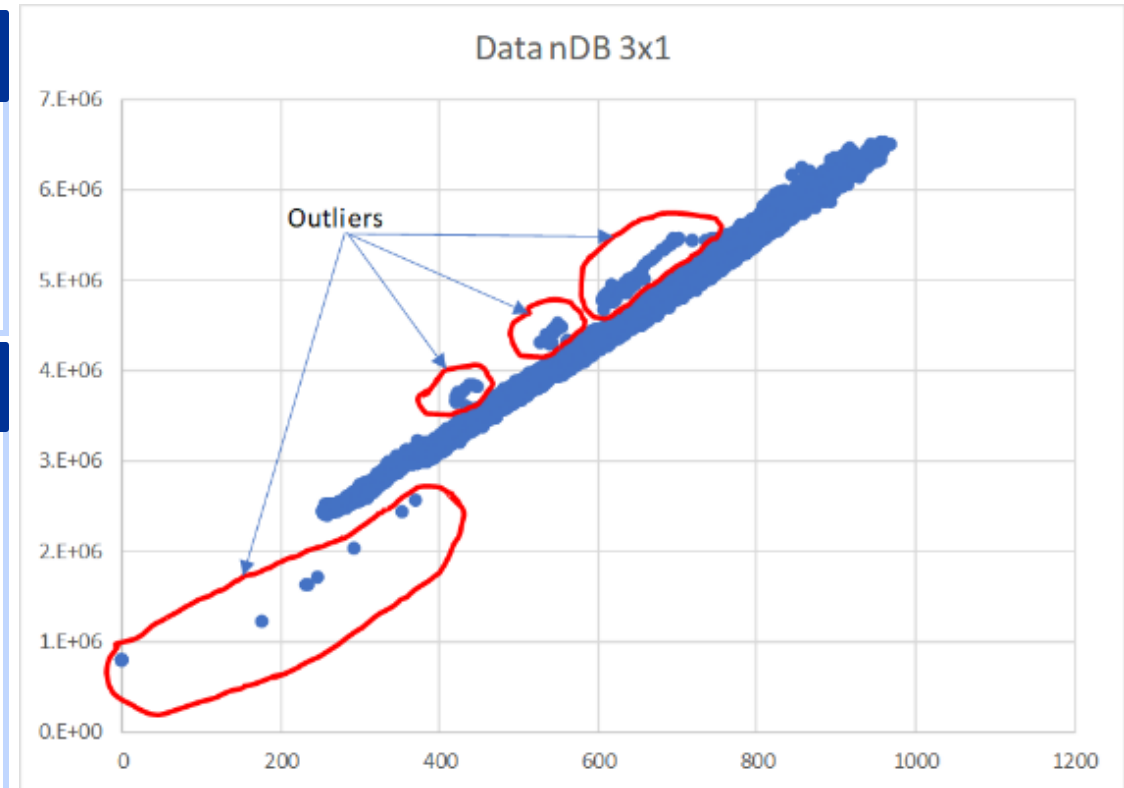
## Key Developments and Updates

In 2023, we executed a project to develop standardized dispatch curves using a data mining technique that used the significant amount of plant data that is now available for most units to develop a more accurate dispatch curve that reflected all levels of operation. This curve can then be verified and updated as needed. The details can be found in the following:

Developing Consistent Heat Input Curves for More Accurate Dispatch:  
Conventional and Combined Cycle Units

<https://www.epri.com/research/products/000000003002028474>

In 2025 we would like to employ this same methodology to a Rankine cycle unit. We feel there is significant advantage not having to schedule a test and go to a preset load for a certain period just to check a curve, and the data mining method verifies performance at reduced loads as well where many plants are spending most of their operating hours.



*Outlier Analysis*

## Schedule and Upcoming Work

Potential Supplemental Project initiative for interested plants. For details, contact Keith Paul at [kpaul@epri.com](mailto:kpaul@epri.com).



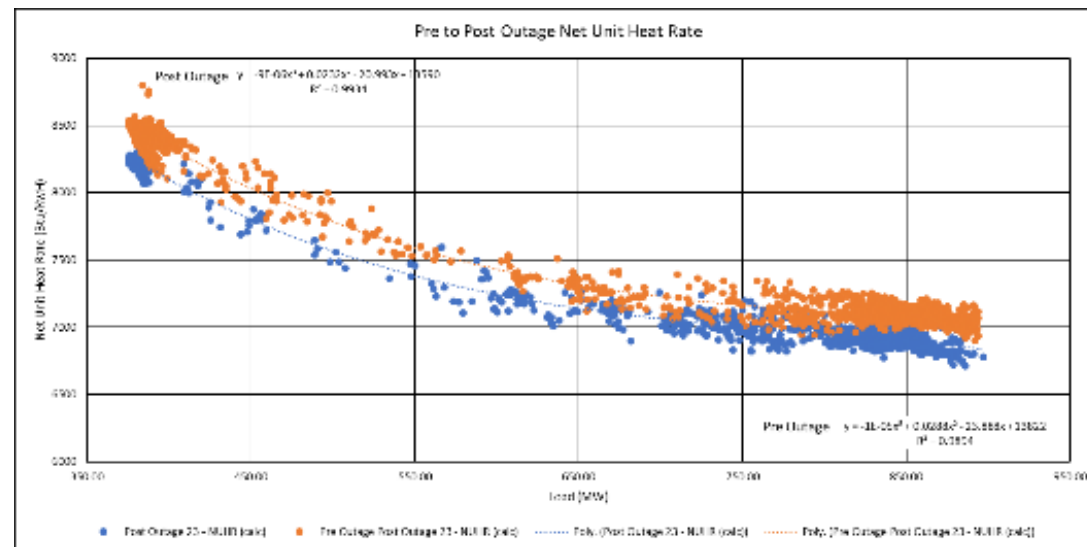
# Pre and Post Outage Performance Testing

## Project Objective and Scope

Many plants do not quantify the benefits of the significant work performed during outages. Performance Test Code testing is time consuming and expensive. Fortunately, online systems are consistent, repeatable, and utilize installed instrumentation to provide analysis on a consistent basis that can be compared from outage to outage to track performance and plant degradation. On-line tools allow quantification of part-load outage benefits where historical testing was typically only performed at baseload.

In 2023 we developed a method for executing Pre and Post Outage performance Tests using a data mining technique that can be setup in the plant control or performance monitoring systems that can utilize existing plant data to execute these test in a comparable manner that can be used now and, in the future, to determine how much performance was gained during an outage. Pre- and Post-Outage Performance Testing Conventional and Combined-Cycle Units [Pre- and Post-Outage Performance Testing: Conventional and Combined-Cycle Units \(epri.com\)](#)

In 2025, we would now like to execute this on a Rankine cycle unit as part of next steps.

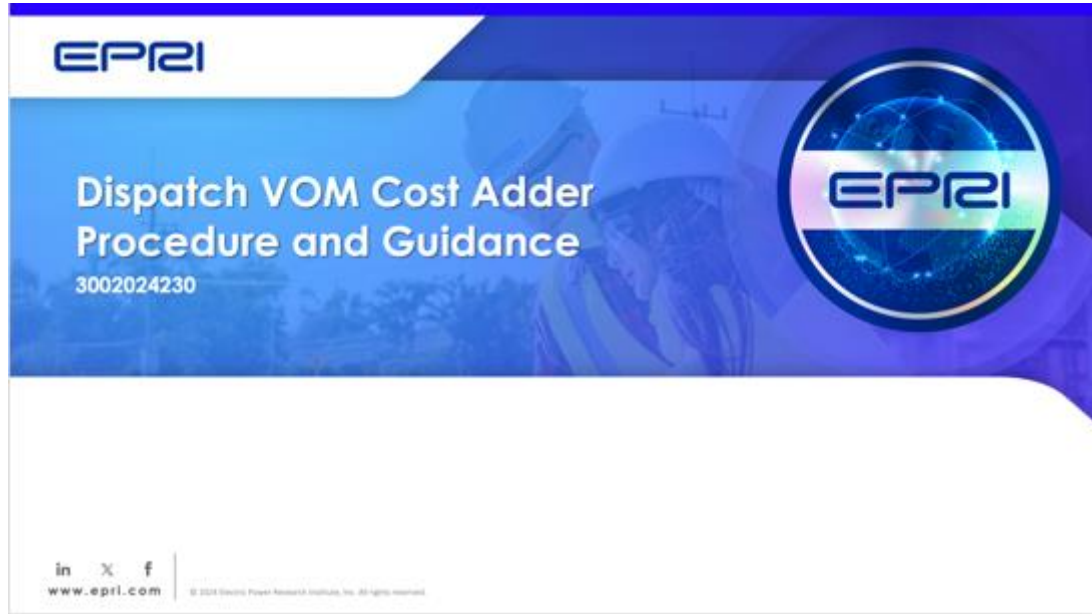


## Schedule and Upcoming Work

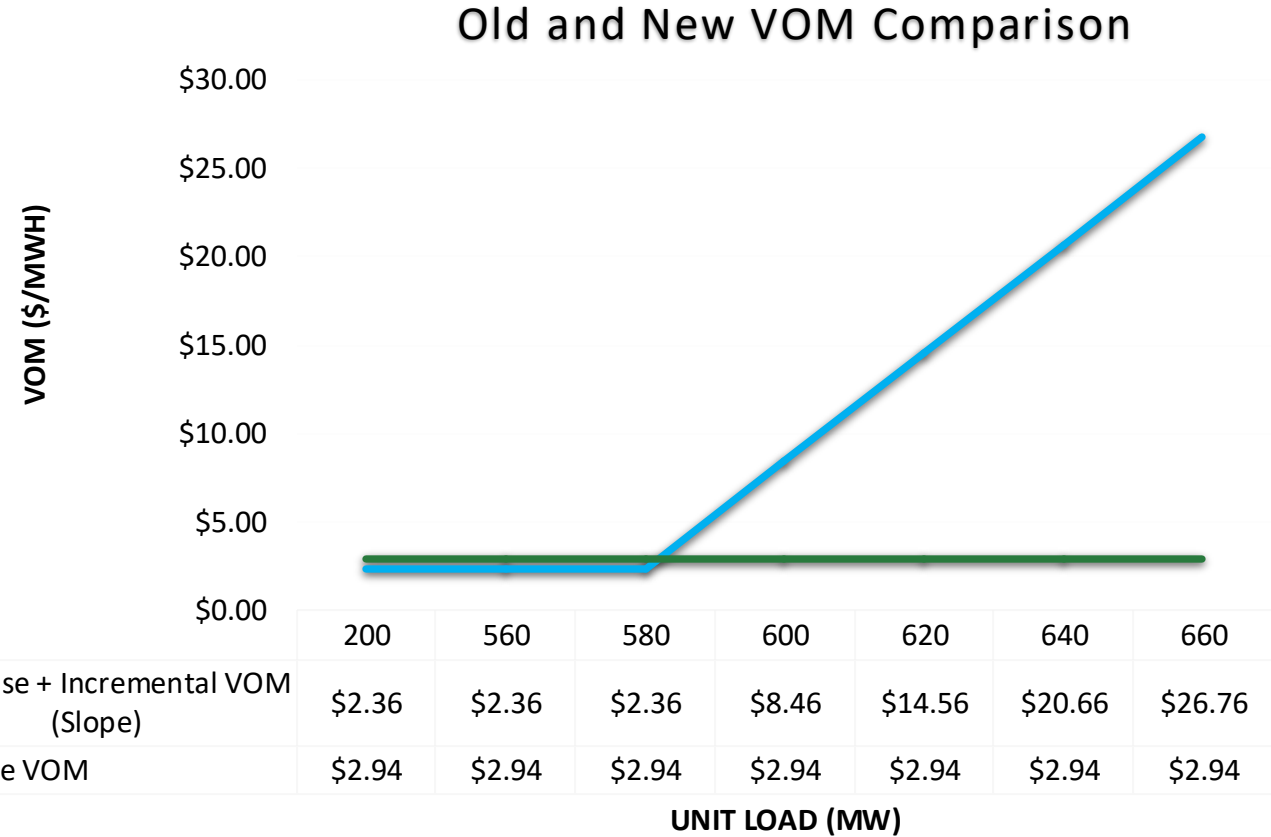
Potential 2025 unit specific Supplemental depending on outage schedules For details, contact Keith Paul at [kpaul@epri.com](mailto:kpaul@epri.com).

# VOM “Cost Adder” - Strategy Adoption Recommendation

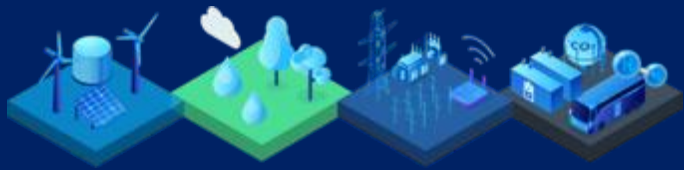
Certain forced outages and equipment damage can be caused by operation in specific load ranges (typically high load). The associated outages and damage causes economic opportunity losses and repair cost for customers and investors. Consistent with economic dispatch, adjustments to the VOM rate (\$/MWH) for dispatch cost/bidding can be appropriate for certain load ranges. This improves the reflection of actual risk and incursion of costs and can be a cost-effective failure mitigation strategy.



<https://www.epri.com/research/products/000000003002024230>



## Variable O&M Cost Recovery Strategy for Dispatchable Generation



# Flexible Operations Cost Management Tool

## V2.0 - 2024 Update

### Project Objective and Scope

- Understanding and forecasting cost & risk is a necessary part of conducting business
- Operationalize industry cost and reliability data and models for utilities managing flexible operations
  - Engage **beyond resource planning**
  - Develop more **robust & granular** cost model

### Key Developments and Updates

- Updated Flexibility Cost Tables
- Development of CCGT-Specific Template
  - Allows reallocation of hours/starts across CTs
- Scenario Comparison Capability
  - Develop multiple future flexibility cases
  - Compare total scenario costs
- Additional calculations based on market/member need
  - \$/run hour feature incorporated

Project Manager: Grant Lanthorn | 252.621.4428 | glanthorn@epri.com

### Cost & EFOR Impacts – Reference Tables

Unit Types	Cool - Small Sub Critical	Cool - Large Sub Critical	Cool - Super Critical	Gas - Steam	Gas - Large Frame CT	Gas - Aero Derivative	Typical CC [OT+HS]	High ER - CC [OT+HS]	Fast Start - CC [OT+HS]	Gas - Recip. [per Engine]
<b>Typical Hot Start Data</b>										
-CAM cost (\$/MWh cap.)										
Median	89	58	63	38	44	31	47	51	37	
*25th_percentile	75	38	45	26	20	12	37	41	31	
*75th_percentile	124	66	79	44	111	60	75	80	75	
<b>Typical Warm Start Data</b>										
-CAM cost (\$/MWh cap.)										
Median	139	76	82	58	53	31	58	65	52	
*25th_percentile	99	55	63	36	21	12	34	38	30	
*75th_percentile	205	79	104	87	119	60	98	125	87	
<b>Typical Cold Start Data</b>										
-CAM cost (\$/MWh cap.)										
Median	179	134	133	83	63	32	83	93	80	11
*25th_percentile	97	70	89	60	32	12	48	54	46	7
*75th_percentile	317	153	147	99	126	60	107	143	102	13
Startup Time (Hours)										
Typical (Warm Start Offine Hours)	0 to 14	14 to 22	14 to 22	0 to 14	1 to 3	0 to 1	1 to 40:07 (offline)	1 to 40:07 (offline)	1 to 40:07 (offline)	0 to 1
<b>Typical Load Follow Data</b>										
-CAM cost (\$/MWh cap.) - Typical Ramp Rate										
Median	3.34	2.45	1.96	1.92	1.59	0.63	0.64	0.64	0.64	0.64
*25th_percentile	1.91	1.40	1.52	1.57	0.94	0.42	0.30	0.30	0.30	0.30
*75th_percentile	3.84	3.33	3.38	2.32	2.80	1.20	0.74	0.74	0.74	0.74
Range of Load Follow (%GDC)										
Typical Range (%GDC)	32%	35%	30%	32%	27%	20% (Diverse 50%)	20%	20%	20%	20%
Multiplying Factor - Faster Ramp Rate (1.1 to 2x)										
Range*	2 to 8	1.5 to 10	1.5 to 10	1.2 to 4	1.2 to 4	1 to 1.2	1.2 to 4	1.2 to 4	1.2 to 4	1.2 to 4

Note: Multiplying factor - increase in load follow cost (derived from a faster ramp rate)

Update of Reliability and Cost Impacts of Flexible Generation on Fossil-fueled Generators for Western Electricity Coordinating Council

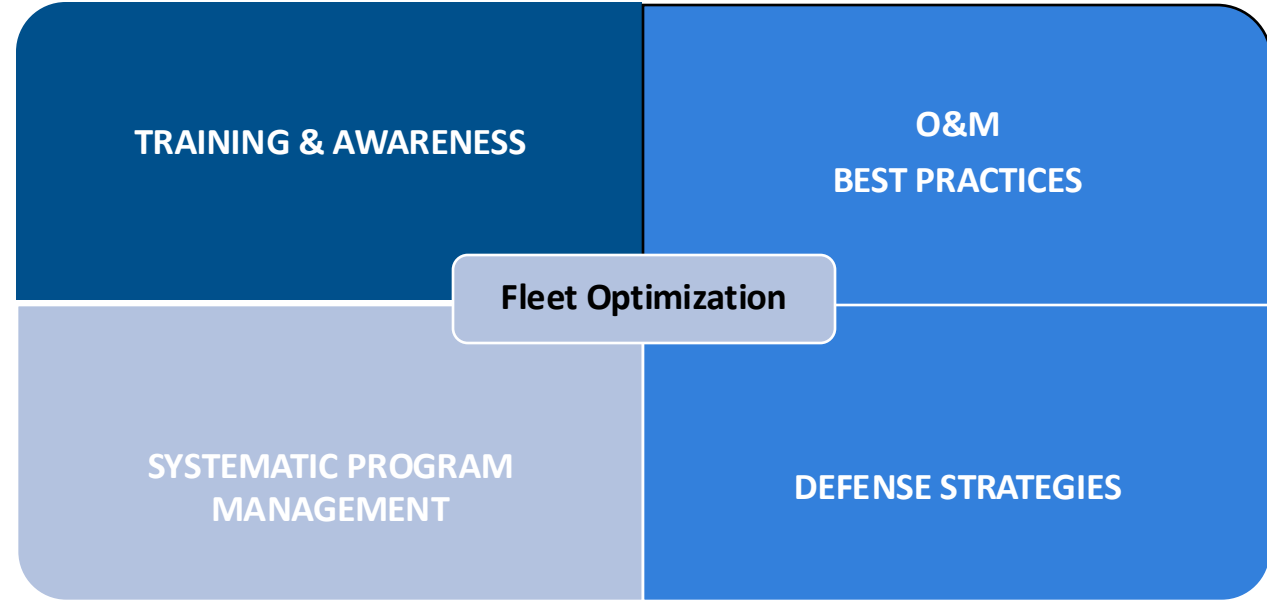
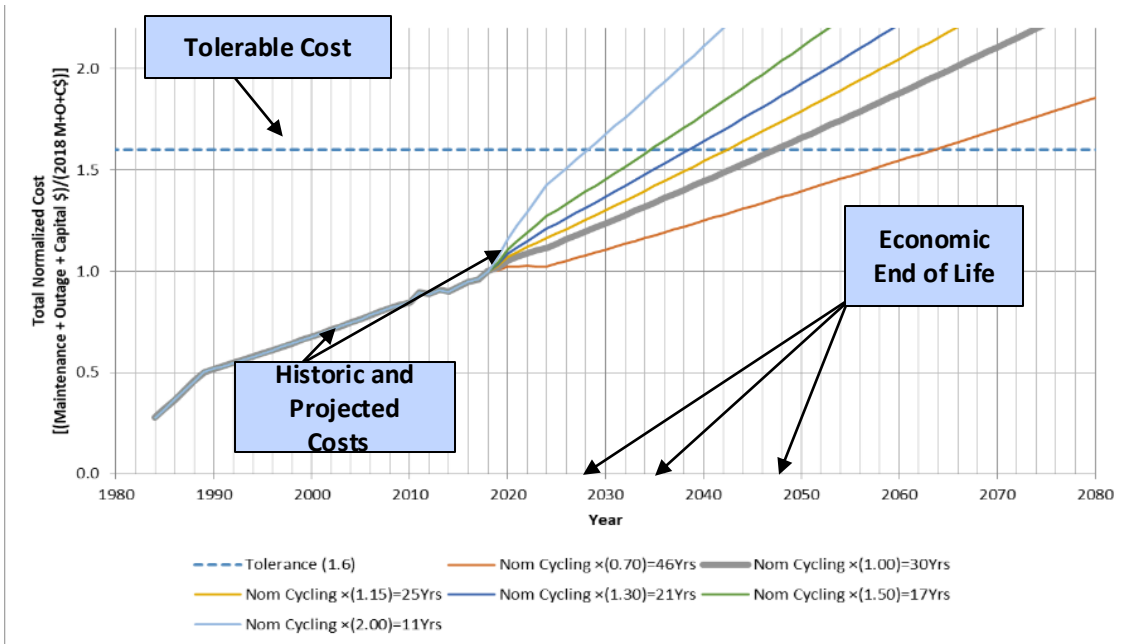
### Schedule and Upcoming Work

V2.0 Released 12/31/2024

- Support Base/Supplemental Research
- Identify additional features & incorporate into plan

[Download Link](#)

# Case Study – Coal Plant

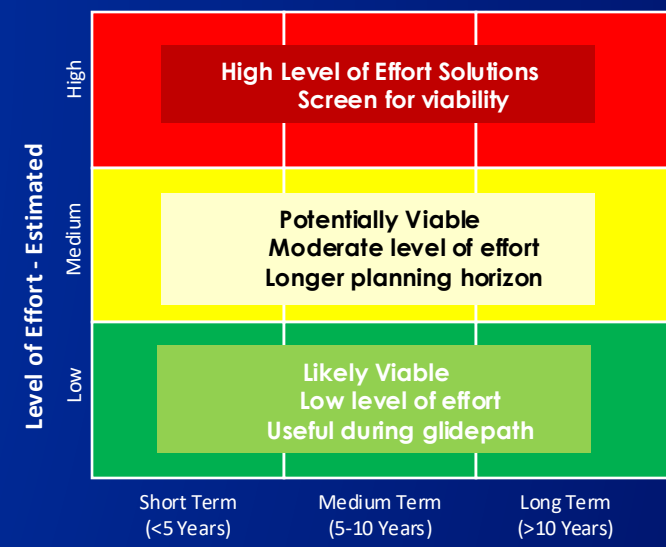
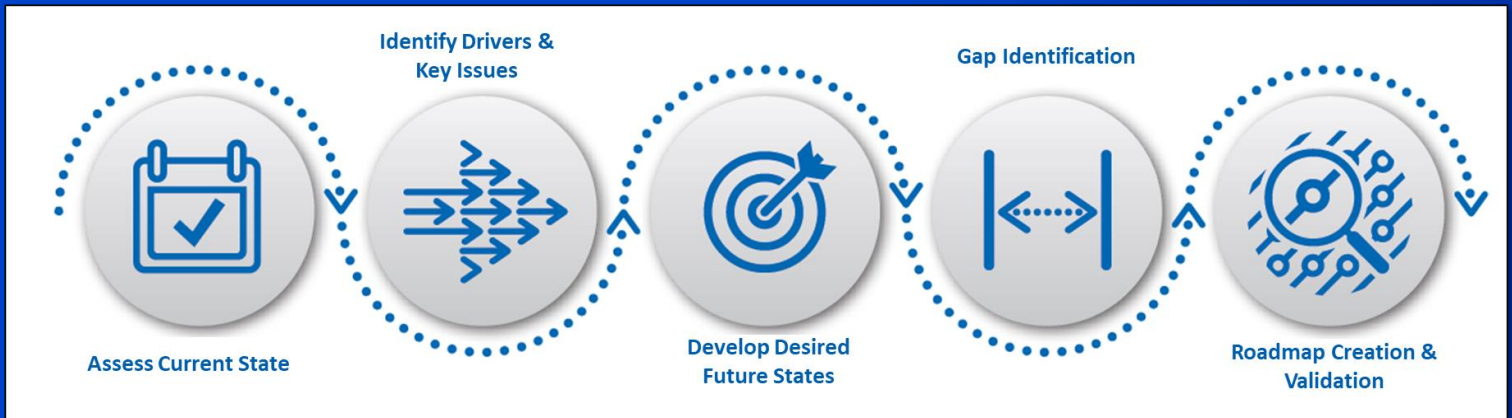


## Flex Strategy

Priority Issues

Slow Burns

Showstoppers



# Cost Management Tool Insights

The Cost Management tool provides valuable insights by:

1

**Quantifying the Lower Bound:** It establishes a minimum cost expectation for cycling operations.

2

**Highlighting Potential Cost Risks:** The concept of a statistical distribution emphasizes the possibility of exceeding the lower bound estimate.

3

**Informing Investment Decisions:** By understanding the potential cost range, decision-makers can make more informed investments in plant upgrades or maintenance strategies with **activity-based costing**



# Steam Turbine Bypass Valves

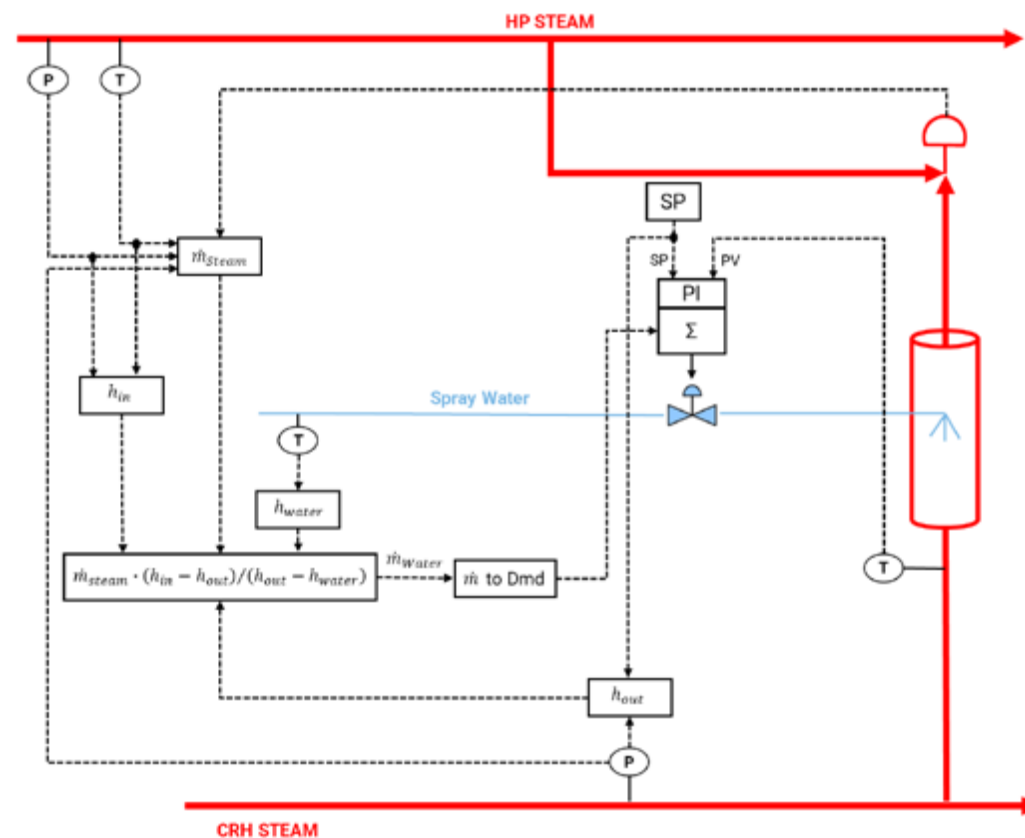
(Collaborative P223, P215 and P227 Project)

## Project Objective and Scope

- To evaluate the current deficiencies in performance and past failure problems.
- To evaluate improved control strategies and scenarios
- To minimize or eliminate critical failures in the future

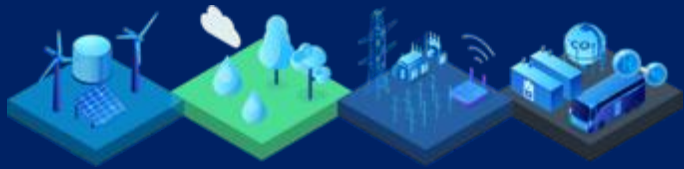
## Key Developments and Updates

- Adding control logic recommendations for the LP bypass valves and temp controls
- Updating the plots to the deliverable that we developed last year
- Running more simulations with the steam bypass model we developed last year and potentially start implementing an enthalpy controller
- Working to deliver the steam bypass model developed last year to members. Updating the model with improvements to control strategy such as enthalpy control as a result of simulations.
- Evaluating the conditions occurring downstream of the sprays with the flow leaving the attemperator contacting and being measured by downstream thermocouples during all system loads.



## Schedule and Upcoming Work

Work to be executed in 2025



# Flexible Operations Case Studies

## High Energy Piping – Collaboration w/P215

### Project Objective and Scope

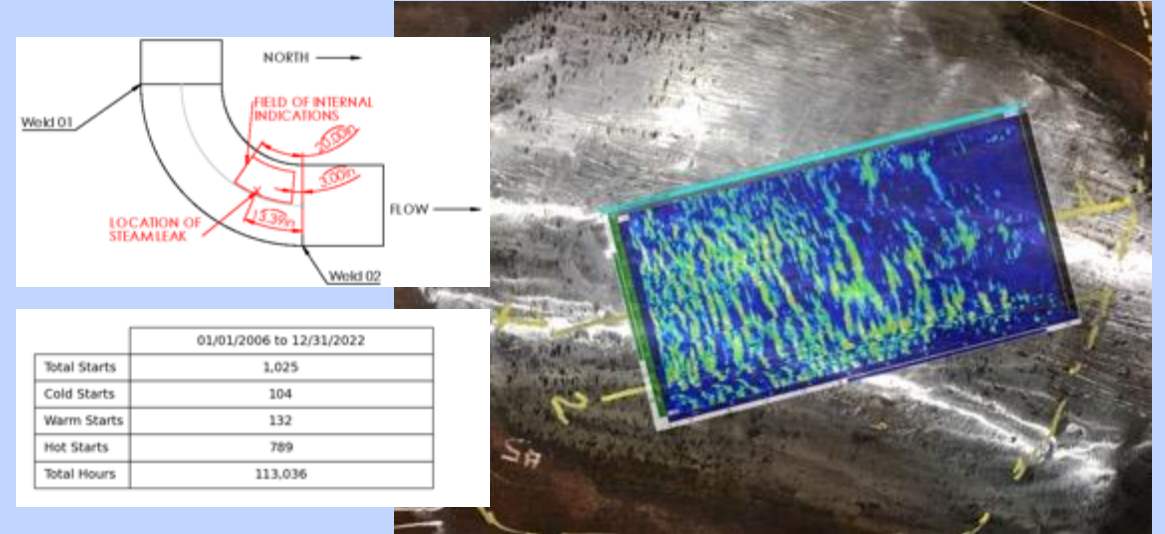
- Detailed case studies using a common template:
  - Incident description and plant details
  - NDE/Metallography/Data Review
  - Further information and resources

*High-level overview of events to be mindful of*

### Key Developments and Updates

Case 1: Potential Quenching & Water Hammers in CCGTs	Case 6: Reheat Interstage Attemperator Piping Cracking due to Thermal Fatigue
Case 2: Hot Reheat Bypass Pipe Cracking	Case 7: Hot Reheat Bypass Desuperheater Piping Cracking and Water Hammer
Case 3: Main Steam Piping System Thermal Fatigue	Case 8: Effect of Flexible Operation on Main Steam System Creep Life Predictions
Case 4: Thermal Quenching on HP Steam	Case 9: Effect of Flexible Operations on Cold Reheat System Integrity
Case 5: Cold Reheat Non-Return Valve Failures	

**Project Manager:** Tom Sambor | 704.595.2456 | [tsambor@epri.com](mailto:tsambor@epri.com)



### Schedule and Upcoming Work

2024 Deliverable

Webcast: [High Energy Piping \(HEP\) Case Studies: Flexible Operation Impacts](#)

[Download Link](#)



# Flexibility Issues and Solutions Database

## FLEXOPS.EPRI.COM



### Project Objective and Scope

Tools for Managing Flexible Operation of Power Plants

SPN 3002016820

EPRI Flexible Operations Database

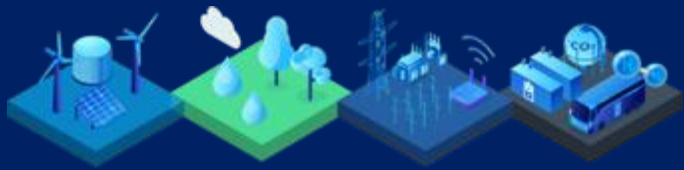
Search Criteria

Priority	Article	Unit Types	Witness	Issue	Description
HIGH	STG7	Combined Cycle	Cycling (On / Off)	L-C blade cracking and new OEM "exclusion zones" under load following at low load operation	Blade flutter vibration at certain combinations of unit load and backpressures can create operational "exclusion zones". The stress blade designs are being discovered by the OEMs based on field experience
HIGH	STG6	Combined Cycle	Cycling (On / Off)	The generator rotor is most vulnerable to low cycle fatigue caused by starts and stops. Accelerated life accumulation of steam turbine casings and valve bodies due to factor 2 thermal stresses	This issue deals mainly with the start windings and end turns and it's caused by differences in thermal growth between forging, insulation, and copper.
HIGH	STG4	Combined Cycle	Cycling (On / Off)	Life cycle management of main generators, accelerated damage due to flexible operation	Thermal-mechanical fatigue cracking in valve bodies and casings due to frequent starts and excessive load ramping. Some evidence that this is OEM-specific
HIGH	STG3	Combined Cycle	All Load	Optimize intervals between out-of-service/repairs to reduce maintenance costs	Generator stator winding, in particular the end winding, will experience uneven thermal expansion during full MVA ramping. This will lead to accelerated loosening of the end winding blocking, vibration and abrasion of the stator bar insulation life don't know the impact of cyclic operation on these components. Insulation, coils, retaining rings, rotor coil matching, brushes and/or matching top-bottom matching need technical leads Cold connections, flux leads, main lead copper, main lead seals, and cross over leads not monitored regular intervals—cycles failure influence Accelerated winding aging due to thermal cycling stator/field embedding vibration increases—due to thermal growth wear from cycling Steering and hydrogen seal impacts during startups

EPRI Flexible Operations Database

Search Criteria

Title	Article #	Unit Types	Witness	Issue	Description
L-C blade cracking and new OEM "exclusion zones" under load following of low load operation	STG7	Combined Cycle	Cycling (On / Off)	L-C blade cracking and new OEM "exclusion zones" under load following of low load operation	Blade flutter vibration at certain combinations of unit load and backpressures can create operational "exclusion zones". The stress blade designs are being discovered by the OEMs based on field experience
Need for more frequent L-C blade NDE. Unit control data frequency not sufficient to ensure that avoidance zone is avoided during load changes					Consequences of OC ST blade vibration is severe
Operate unit outside the stated exclusion zones OEMs are recommending modifications to blades (stiffening) to reduce flutter. Installing new turn heating to suppress flutter					Staying outside exclusion zones significantly impacts unit flexibility New blade rises are expensive
Get turbine Component Quality Characteristics, Initial Experience with Process Computerized Resonance Testing, Fat Multiaxial Evaluation, Process Control, and Online Data Run					Impact of high Cycling Demand on Combined Cycle Steam Turbines



# Technoeconomic Studies in Flexible Operation: Evaluating Flexible Operation Costs for Energy Market Participation

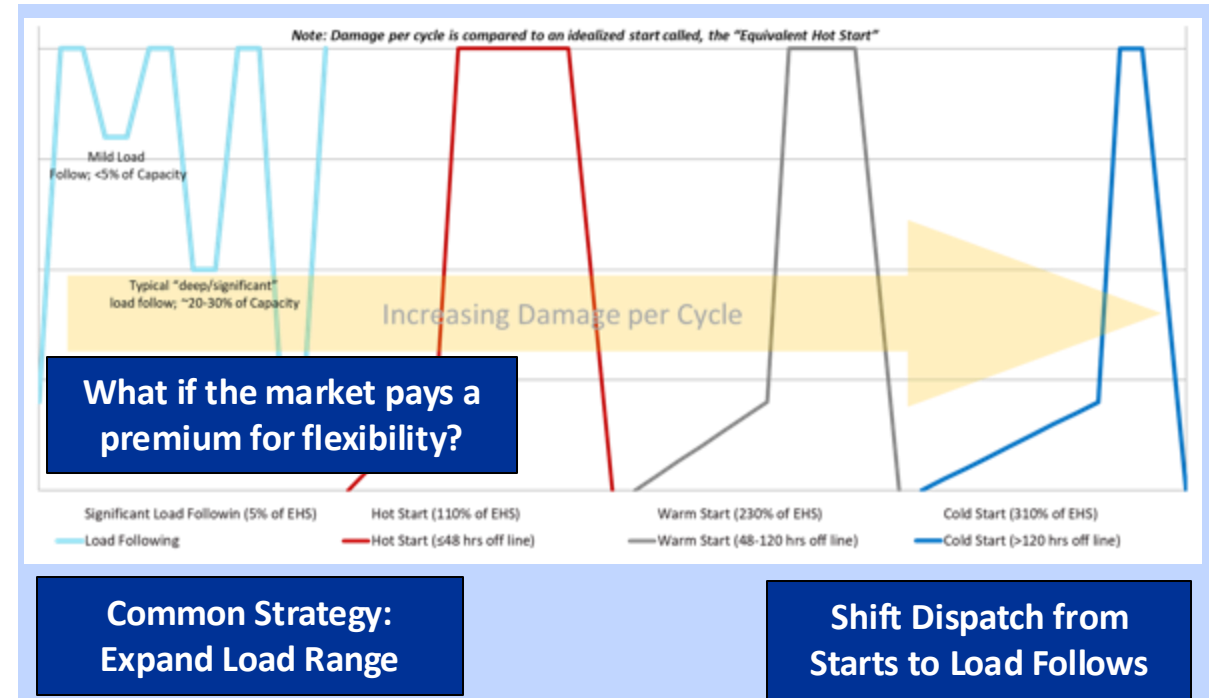
## Project Objective and Scope

- EPRI research shows relative cost of flexible operation is lowest when starts are avoided
- Different regions and markets have various approaches to managing market risk
- Apply a flexibility cost methodology to a member utility
- Offer the methodology & sanitized results

## Key Developments and Updates

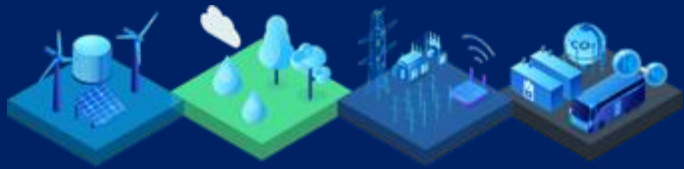
- Partner with a member utility
- Identify flex-ops related costs for a given market
- Develop a methodology to share and refine
- Calibrate model against production cost model and market pricing mechanisms
- Support commercial interests by provide additional resolution on flexible energy market costs and revenue

**Project Manager:** Grant Lanthorn | 252.621.4428 | glanthorn@epri.com



## Schedule and Upcoming Work

- Identified member participant and technical support
- Conduct initial analysis, review with member, summarize and sanitize for release



# Economic Justification of Flexibility Projects

## Project Objective and Scope

- Develop overall database/calculator structure; Define inputs and outputs & collect relevant information
- Evaluate known or estimated cost and benefits of flex retrofits on existing plants
- Bottom line – **EBITDA impacts & payback period**

## Key Developments and Updates

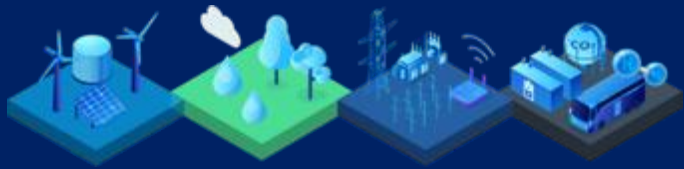
- Finalizing MS Excel Spreadsheet
  - U/I – MS Excel
  - Business Logic – **Majority of effort**
  - Underlying Data – Seeded with examples
- Case Studies Template – *What happened?*
- Cost/Benefit Template – *What's the value?*
- **Continue database expansion** through internal EPRI, membership and/or external resources

**Project Manager:** Grant Lanthorn | 252.621.4428 | glanthorn@epri.com

Site Inputs		
Generator Gross Nameplate Capacity	MW	400
Type of Power Plant		Coal - Small Sub Critical
Capacity Factor, Current	%	55%
Annual Start Count	#	200
Production, Current	MWh	1,927,200
Annual Flexible Generation Cost	\$	\$13,070,700
Annual Flexible Generation Cost (Starts Only)	\$	\$12,856,900
Forecasted Market Potential		
Enter Annual Price	\$/MWh	<a href="#">Revenue Potential</a>
Retrofits and Investments		
Retrofit Option		Add steam cooled enclosure min flow protection for balanced flow with blow down or dump to LP turbine
Project Useful Life	years	5

## Schedule and Upcoming Work

- Documentation development
- Build underlying data set
- Real world testing: Member + projects + cost/dispatch



# Economic Justification of Flexibility Projects

**Discounted Cash Flow Analysis:**  
Net present value of future cash flow

**EBITDA:**  
Where value is realized

**Bottom Line:**  
Internal Rate of Return  
Payback Period

Project Year	units	0	1	2	3	4	5	6	7
<b>Plant Capacity</b>									
<b>Production Change</b>			0.0%	-5.0%	0.5%	0.2%	0.0%	0.0%	0.0%
Plant Capacity Factor by year (%)			55.0%	52.3%	52.5%	52.6%	52.6%	52.6%	52.6%
<b>Annual Production</b>	<i>MWh</i>		1,927,200	1,830,840	1,839,994	1,843,674	1,843,674	1,843,674	1,843,674
<b>Production</b>	<i>MWh</i>		1,927,200	1,830,840	1,839,994	1,843,674	1,843,674	0	0
Market Revenue	<i>\$/MWh</i>		35.00	35.80	36.62	37.45	38.30	39.16	40.05
Revenue		\$	67,452,000	\$ 65,544,072	\$ 67,373,228	\$ 69,042,501	\$ 70,607,718	\$ -	\$ -
<b>Expenses</b>									
Operating Expense Inflation Factor			1	1.020	1.040	1.061	1.082	1.104	1.126
Fixed O&M Expense	\$		(\$1,600,000)	(\$1,632,000)	(\$1,664,640)	(\$1,697,933)	(\$1,731,891)	\$0	\$0
Variable O&M Expense	\$		(\$38,544)	(\$37,349)	(\$38,287)	(\$39,130)	(\$39,913)	\$0	\$0
Annual Flex Gen Cost	\$		(\$13,070,697)	(\$13,070,697)	(\$13,070,697)	(\$13,070,697)	(\$13,070,697)	\$0	\$0
Annual Fuel Cost	\$		(\$46,100,435)	(\$46,457,164)	(\$48,802,681)	(\$52,388,603)	(\$55,718,471)	\$0	\$0
<b>Total Operating Expenses</b>	\$		(\$60,809,676)	(\$61,197,210)	(\$63,576,304)	(\$67,196,363)	(\$70,560,972)	\$0	\$0
Op Exp	<i>\$/MWh</i>		(\$31.55)	(\$33.43)	(\$34.55)	(\$36.45)	(\$38.27)	\$0.00	\$0.00
<b>EBITDA (Operating Income)</b>		\$	6,642,324	\$ 4,346,862	\$ 3,796,924	\$ 1,846,138	\$ 46,746	\$ -	\$ -
<b>Project Cash Flows</b>									
Change in Flex Cost			\$5,914,191	\$5,914,191	\$5,914,191	\$5,914,191	\$5,914,191	\$0	\$0
<b>Investment</b>		(\$625,000)							
		\$	6,642,324	4,346,862	3,796,924	1,846,138	46,746	-	-
		(\$625,000)	\$12,556,515	\$10,261,053	\$9,711,115	\$7,760,329	\$5,960,937	\$0	\$0
Running IRR			1909%	1988%	1991%	1991%	1991%	1991%	1991%
<b>Discount rate</b>			1.0	0.9	0.8	0.8	0.7	0.6	0.5
Cumulative Cashflow		(\$625,000)	\$11,931,515	\$22,192,568	\$31,903,683	\$39,664,011	\$45,624,949	\$45,624,949	\$45,624,949
Present Value of cash flows		(\$625,000)	\$11,415,014	\$8,480,209	\$7,296,104	\$5,300,409	\$3,701,273	\$0	\$0
<b>IRR</b>									<b>1991.2%</b>
<b>Payback</b>			1.0	0.0	0.0	0.0	0.0	0.0	0.0

# Retrofit Database - Customizable & Expandable

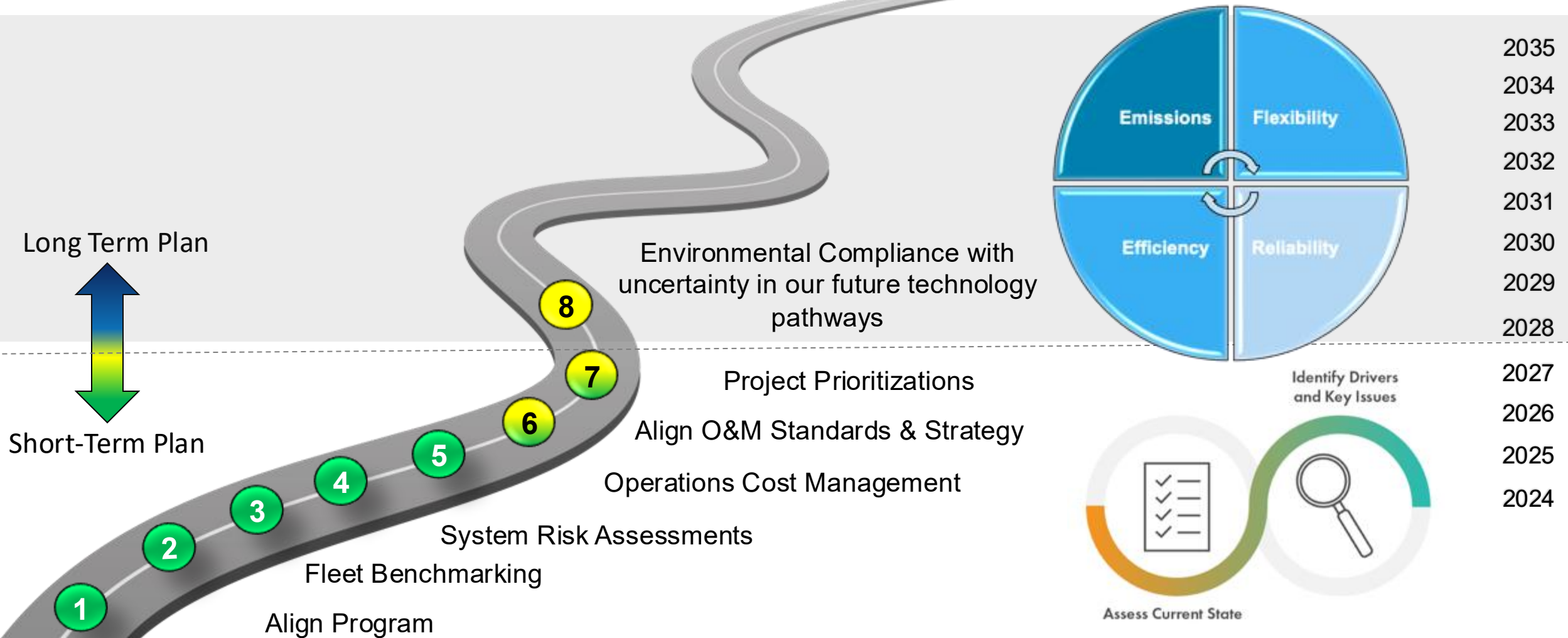
Retrofit Options	\$M	Potential Impact		
Description	Cost	Ramp Rate	Improve Turndown	Startup/ Shutdown
Boiler optimization using revised procedures	\$ 0.50	33%	33%	33%
Revised procedures for cycling total plant	\$ 0.50	33%	33%	33%
Improved and automated boiler drains	\$ 15.00		50%	50%
Steam flow redistribution and metallurgy improvements in in SH/RH	\$ 5.00	33%	33%	33%
Steam coil air heater to pre warm boiler and airheater	\$ 1.00	33%	33%	33%
Gas bypass to keep air heater warm	\$ 1.50		50%	50%
Improved APH basket life when cycling in or through the wet flue gas temperature region by installing traveling APH blowers to remove deposits prior to cycling down in load	\$ 1.00		50%	50%
Improved APH basket life with improved materials when cycling in or through the wet flue gas temperature region	\$ 2.00		50%	50%
Improved selected expansion joints.	\$ 2.00			100%
Add steam cooled enclosure min flow protection for balanced flow with blow down or dump to LP turbine	\$ 0.50		50%	50%
Improved flame proving equipment for burners	\$ 1.00	33%	33%	33%
Low load gas ignitors to allow min generation on gas fuel only	\$ 3.00		100%	
Dual Fuel burners – use NG over coal . (Add NG to all burners).	\$ 12.00	33%	33%	33%
New feeders with gravimetric type feeder with improved weighing of coal feed to mill	\$ 7.20	33%	33%	33%
Automatic pressure control on roll and race to adjust the grinding pressure of the coal mill.	\$ 5.00	33%	33%	33%
Heated precipitator hoppers	\$ 1.00		50%	50%

**Seeded from industry R&D**  
**Users Can Modify or Add New Retrofits**

# Thermal Optimization and Emissions Controls: Strategic Roadmap Planning



Strategic Roadmap Planning



# Preparing for Future Demands

- Heat rate improvements in a power plant improve air emissions and contribute to the overall reliability and life of the plant.
- Flexibility has a direct relationship on the ability to integrate additional variable energy resources.

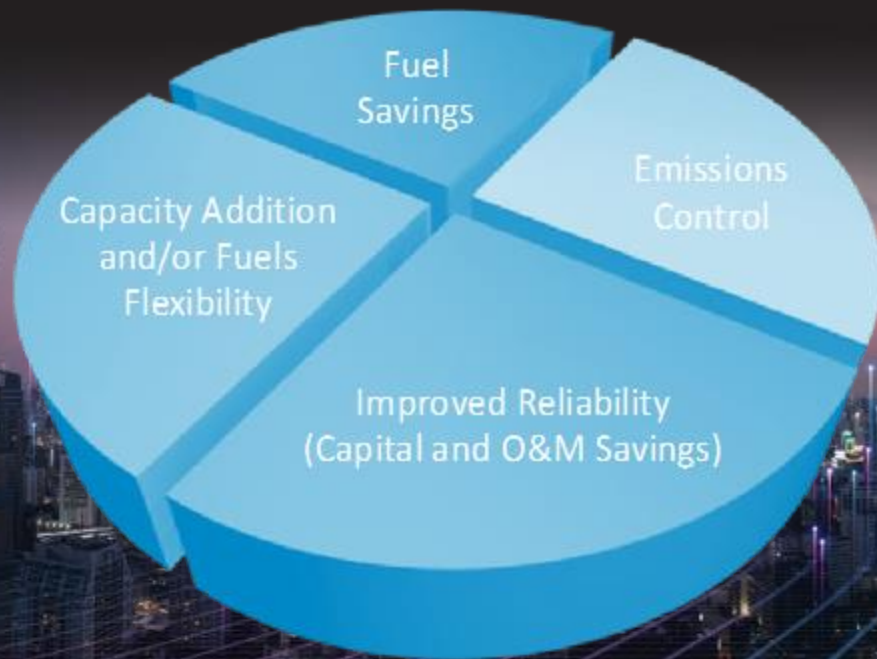
- Emerging Technologies; Supply Chain Disruptions
- Plant O&M management
- Improvements to reduce air emissions are one-for-one (e.g., 2.5% heat rate improvement = 2.5% reduction in all air emissions, including carbon dioxide [CO<sub>2</sub>] and nitrogen oxide [NO<sub>x</sub>]).

- Fuel Supply Security (dual fuel capability; onsite storage; Oil, Gas, Coal, Other)
- Because the cost of fuel is 60–80% of the overall cost of producing electricity, improvements in heat rate can make a difference in the financial health of a power plant, power producing company, and the power industry.
- Environmental Compliance



# THE ENERGY TRANSFORMATION

Accelerating towards clean, affordable, reliable, and resilient energy for everyone.



## OPTIONALITY

Leveraging the full portfolio of existing and emerging energy resources while accounting for regional differences



## INNOVATION

Developing and deploying innovative solutions across the clean energy economy



## COLLABORATION

Reaching across industry and government to align technology development and deployment with customer needs



# Questions

**Stephen Storm, EPRI**

Area Manager

Thermal Optimization and Emissions Controls

<https://www.epri.com/research/programs/113126>



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**TOGETHER...SHAPING THE FUTURE OF ENERGY®**