Digital Energy Solutions for Power Generation

Transformative, modular, and interoperable tools for a changing industry

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Power Generation Utilities have never had it easy, however, today's challenges are increasing in complexity and coming at greater speeds. In order to stay competitive, power generators must transform operations, reduce costs, unlock new opportunities and adapt as more renewable sources come online.

This paper examines the promise of Industrial Internet of Things (IIoT) applications for power generators to help overcome these challenges. In particular, this discussion outlines the value of modular, interoperable IIoT solutions working together to deliver exceptional benefits and outcomes . Examining three hypothetical scenarios in detail, this paper highlights digital transformation's support of:

- Optimizing energy production to capture peak pricing
- Prioritizing asset capacity
- Managing maintenance needs

Digital innovations available today offer a range of solutions to power companies' operational challenges. Ultimately, a unique competitive advantage comes from having access to— and ability to glean insights from—the right data.

GE has been a leader in engineering, building, and maintaining power plants for more than 125 years. In partnership with some of the largest utilities and power generators on the planet, GE's equipment helps manage the flow of electricity globally. With experience comes data, and GE is uniquely equipped to deliver IIoT applications that are transforming the power industry.

Today, GE's Digital Energy solutions run on a more secure, scalable platform that standardizes the storage and consumption of data across the energy value chain, from power generation to consumption by end users and prosumers. GE unifies data on a platform that applies artificial intelligence (AI), machine learning (ML) and Big Data compute capabilities. This portfolio enables GE and our customers to create solutions that deliver improved performance using a stable, model-driven approach.

For a power generator, interoperable IIoT applications leveraging GE's domain expertise and developed with specific end-users in mind make sense. This modularity provides a cohesive, closed-loop performance management solution that helps to addresses existing problems, identifies opportunities and readies the power generator for a successful future.

Realizing The Full IIoT Promise Requires Integration

In the face of decentralization, deregulation and decarbonization, innovative IIoT solutions hold great promise for the energy industry to improve business operations, increase operational efficiencies, reduce unplanned downtime, and efficiently balance supply and demand. Additionally, IIoT solutions are connecting data and analytics from the sensor to the Cloud and from the maintenance department to the trading desk turning bits and bytes into actionable information. With IIoT solutions power generators are able to improve worker safety, enable predictive maintenance, improve plant performance and challenge information silos across organizations.

Interoperability is essential. Although IIoT solutions offer individual benefits, they prove more powerful and productive when effectively integrated. Instead of needing to bring together a group of asset operators in a room for several days to make decisions, these tools take only minutes to convert data into insights. Now, centralized risk-rollup and fleet-level rollup can be done efficiently and with cost savings across the utility.

Energy companies make their margins by managing assets as efficiently as possible while addressing environmental, health, and safety requirements and meeting changing consumer expectations. Plants are frequently cycling on and off, yet this is damaging and costly due to increased asset wear and tear and adverse heat-rate effects. This need for more flexible operations challenges profit margins and increases capital expenditures (Capex). In fact, Capex in the power and utilities sector "continues to rise, with an estimated increase in 2018 of 14 percent to reach an all-time high of $133.8 billion for the 50 electric and gas utilities S&P Global tracks annually."[1] Today's utilities are investing to integrate renewable resources into the grid, support a flexible power flow, and reduce O&M costs.[2] Reducing systemic waste and having and increased understanding of maintenance requirements with the insights from IIoT solutions could make an enormous difference. According to a recent report from Bloomberg New Energy Finance, digitizing operations and maintenance (O&M) can reduce levelized cost of electricity (LCOE) up to 6%.[3]

The industry is turning to IIoT solutions to eliminate operational uncertainty, reduce systemic waste, and break down operational silos. The three following scenarios each demonstrate the value of modular, interoperable IIoT solutions working together to deliver greater outcomes.

Interoperable IIoT Solutions

Operations Performance Management (OPM) software helps central operations, fleet managers, and power plant managers improve productivity by providing decision support for strategic planning and plant optimization. Offering Performance Intelligence, Production Planning, and Performance Optimization, OPM improves the ROI on capital expenditures.

Asset Performance Management (APM) software helps increase reliability and availability of power plants and power transmission and distribution assets while reducing maintenance costs and unplanned downtime and balancing risk. Connecting power plant, generation fleet, and transmission and distribution grid data sources, and using advanced analytics to deliver value, APM fosters collaboration across the utility.

GE's Digital Worker solutions help fleet operations and maintenance teams operate more efficiently with better compliance and safety outcomes. Operators are freed up from the control room with plant remote operations. A cloud solution provides clarity between operations and maintenance. Technicians – both full time and contracted – use a mobile device tailored to their wing- to-wing business process to execute work orders.

Enhancing Energy Production to Capture Peak Pricing

As the share of renewable energy resources continues to expand, the opportunity for gas plants to balance energy production on the grid is growing:

- Plants servicing vertically integrated utilities or regulated territories, in times of high demand or uncertainty due to variable energy resources, must manage the need for reserve capacity or system emergency response with a focus on reducing O&M.
- Plants competing in an open or wholesale energy market look to capture revenue when energy prices are high, while avoiding penalties from missed targets and reducing the impact of any operational changes on outage intervals.

In both scenarios, safely and reliably extending capacity and augmenting energy production at times of highest demand is important. Point solutions that help to monitor performance, push the assets harder, or offer more into the marketplace start to address these opportunities and challenges. Yet the generators are left to close the gaps to avoid exposure to unplanned down time, lower returns on maintenance than expected, and penalties for not meeting demand. Modular, interoperable tools engineered and configured to meet the needs of specific end users can eliminate these gaps. Components of OPM and APM work together to improve profitability by extending capacity and enhancing energy production.

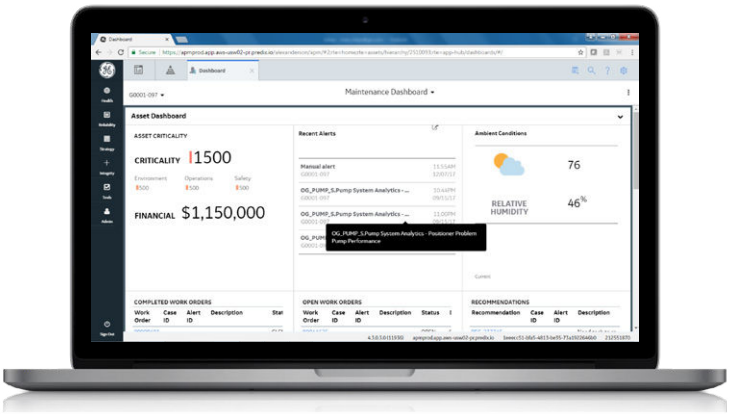
Integration in Action in the ERCOT Region

Consider a 600-MW 2x1 combined-cycle gas plant with duct burners (25 MW each) that participates in the wholesale energy market operated by the Electric Reliability Council of Texas (ERCOT). The historic low reserve margins can lead to significant swings in pricing, especially in the peak summer months.[4]

A plant that runs less frequently and mostly at part load in the spring can find it difficult to assess how degradation is affecting base load output heading into the summer. However, with OPM Performance Intelligence (PI) and APM Health & Reliability (H&R), plant personnel and central operations in the monitoring and diagnostics center have visibility to key performance indicators for the plant, such as ISO-corrected heat rate and output and scorecards for benchmarking in conjunction with issue-prediction reliability analytics. This visibility allows easy detection of plant issues and a clear understanding of recoverable degradation, which enables scheduling of maintenance at most efficient and cost-effective time prior to peak months.

For example, if the steam turbine begins to experience a reduced flow area due to a foreign object or deposition, APM H&R will alert users to a resulting steam flow increase. Additionally, OPM PI would identify a faster than normal reduction in ISO-corrected base load heat rate and output, even if the plant is not operating at base load.

Using OPM and APM Together Can Extend Capacity and Enhance Energy Production



The combination of these alerts would inform the necessary personnel to take action. Unabated, such an issue could lead to a shortfall of up to 16 MWs in output when the plant is expected to peak energy production. In ERCOT in 2018, this could have resulted in $660k loss in revenue during the peak summer months, plus additional fuel costs due to heat rate degradation.[5]

With OPM Performance Optimization (PO), when the plant is operating at part load during the shoulder months, an optimizer coupled with advanced system controls and hot gas path lifing models, enables new modes of operation. By operating the gas turbine at less stressful temperatures while at part load, an energy bank accrues a megawatt hour (MWh) balance at the cost of a small increase in fuel consumption (~0.9% loss in Combined Cycle Efficiency). This bank can subsequently offset the traditional 2 to 3x potential maintenance factor associated with peak firing the gas turbine. This can enable an additional 3.5% of capacity on the gas-steam cycle without increasing O&M costs or impacting the gas turbine maintenance interval. In ERCOT in 2018, for a 600-MW plant and 9400 MWh energy bank, this could have resulted in an extra 17 MW produced during hot ambient conditions for $703k more in revenue during the peak summer months.[6]

Finally, the plant's capabilities can be more effectively monetized in the marketplace with clear visibility to the trading teams. OPM Production Planning (PP) uses real-time information from the plant to continuously assess available capacity and the cost of producing that capacity. With day ahead and intraday insight into each unit's economic minimum and maximum capacity, heat rate at various load points, and anticipated pricing, traders can have the best available information to make decisions.

As an example, by moving from static performance models to machine learning-enabled models, plant personnel and trading teams can be more confident in performance forecasts and not hold back on energy offers. By reducing uncertainty in forecasting, available capacity and its costs, a 600-MW plant can see up to 2% increase in energy offers. In ERCOT in 2018, this could have resulted in $414k increase in revenue during the peak summer months.[7]

Furthermore, pairing OPM PP and PO helps the trading team monetize peak-fire with the optimizer and energy bank by predicting base load and part load hours to recommend an offer price for the peak-fire MWs. The digital solution, then, helps ensure the bank of energy (MWh) are awarded during the periods of highest demand, whether in shoulder or summer. For example, in ERCOT in 2018 for a 600-MW plant and 9400 MWh energy bank, this could have resulted in producing an extra 17 MW, translating into $868k more in revenue during the highest 2828 15-min RTM SPP from March through

Use Case	Tools	Impact on Revenue				
		March - May	June	July	August	Total
Accelerated degradation recovery	OPM PI APM H&R		$166K	$284K	$210K	$660K
Extending capacity and optimizing offer	OPM PO OPM PP	$225K	$138K $104K	$295K $178K	$210K $132K	$1282K
Total		$225K	$408K	$757K	$552K	$1,942K

Table 1. *Benefits of using OPM and APM together extend capacity and enhancing energy production*

Integration in Action

Traditional power plants had little actual insight into what was going on inside their assets. With digital integration, it's possible to know the true state, status, and health of the asset.

In the past, devising an improved strategy to extend the planned maintenance (PM) interval of gas control valves from 24,000 to 32,000 fired hours, required an asset manager to gather spreadsheets from across the utility to understand fleet configuration and reliability. Spreadsheets gathered from enterprise asset management systems (EAMs) are typically populated with mostly miscellaneous failure modes that lack specificity regarding failure causes. The asset manager would press ahead anyway with limited insight into downtime and issue new directives for maintenance. Some sites would implement the strategy and others would continue with the older maintenance practices. Meanwhile, commercial teams were blissfully unaware of any of these actions until a forced outage.

With digital solution integration, asset managers prioritize utility risk and opportunity in a levelized manner in APM. A new maintenance strategy rises to the top to improve reliability and reduce cost. The cross-functional team analyzes the failure modes and devises condition-based strategies to mitigate risk. The new strategy is implemented via APM, which tracks the health of each valve, and Asset Service Management (ASM), where the maintenance history of visual inspections of each valve is maintained. The commercial dispatcher is notified if APM identifies valve health is deteriorating and corrective maintenance is required during the maintenance interval. The asset is de-prioritized and a maintenance crew is lined up. Feedback is recorded via ASM to APM. If a new valve is installed, the technician provides photographic evidence for supervisor verification.

August. This is an additional $165k of revenue opportunity versus simply offering the MWh bank during the peak summer hours.[8]

This single use case for an ERCOT plant (see Table 1) demonstrates the substantial benefits of deploying modular, interoperable tools to extend capacity and enhance energy production in gas plants.

Orchestrating Maintenance Strategy

Fossil-fired power generators are experiencing changes to capacity factor, operating tempo, starts and stops, and load ramping as renewables have grown. Flexibility is essential to accommodate the shift. Yet cycling on and off is costly and damaging. Most traditional plants weren't built for the added starts, stops and ramping of conventional units required today. Significant factors in increased operation and maintenance costs due to cycling include:

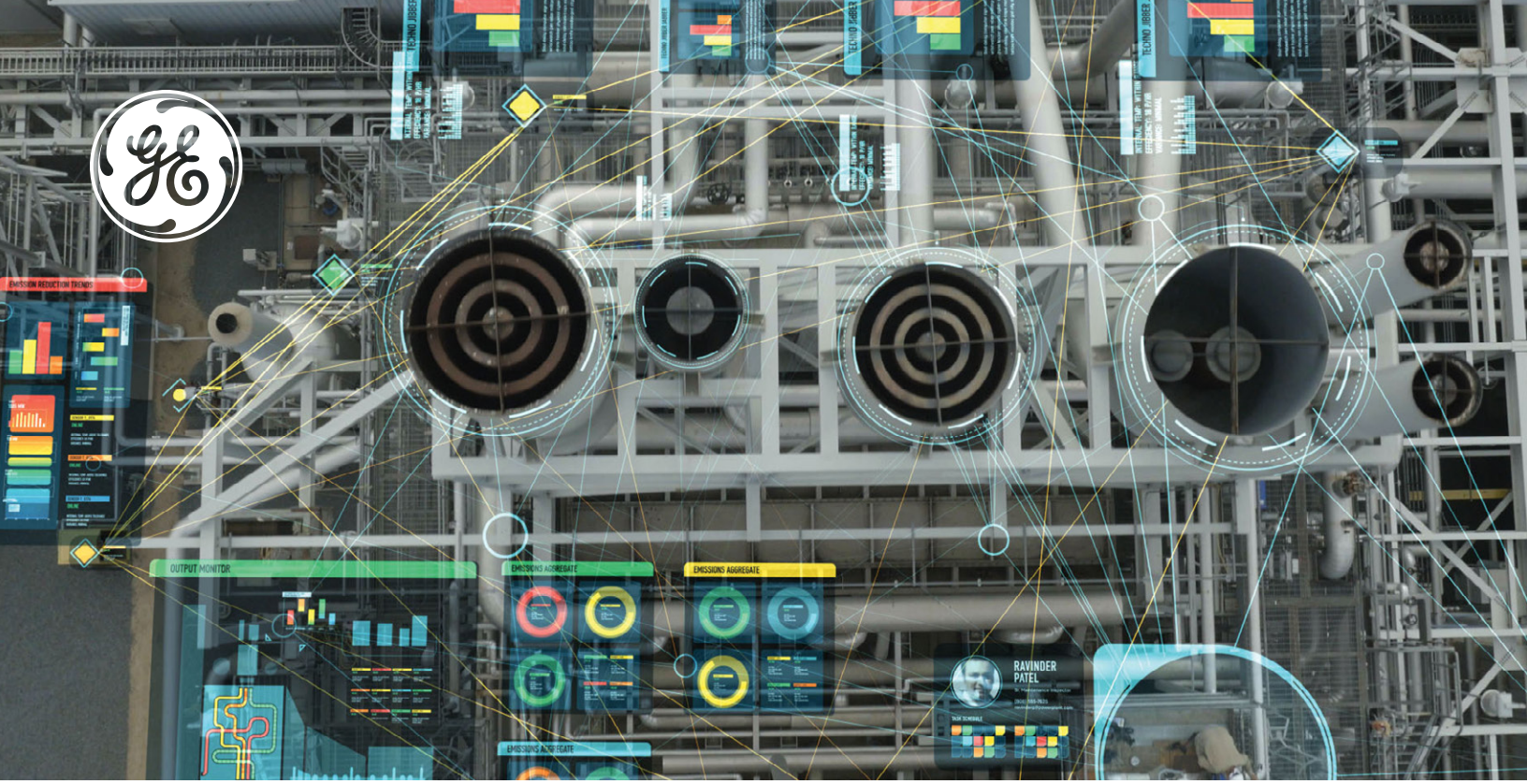
- Thermal fatigue: degradation due to cyclic temperature fluctuations
- Mechanical fatigue: progressive fractures created by fluctuating assets stresses
- Corrosion fatigue: accelerated component failure resulting from fluctuating water chemistry

Today's plants require greater ramping and cycling flexibility, that won't change. Integrated digital technology helps reduce risk and improve the operational cycles for cost recovery. With APM solutions computing actual stresses and damage accumulation to analyze cycling dollar costs, the plant operator can determine impacts of increasing ramp rates, MW load transient ranges and shortened startup times. Additionally, the technologically advanced software helps companies ensure asset safety, reliability and quality.

When maintenance is required, the integrated IIoT toolkit can also prove beneficial.

In the past the necessary digital systems were not available for the cross functional team to orchestrate and implement a cohesive maintenance strategy across a utility:

- Asset managers and operations managers had little insight into assets and had to rely on tribal knowledge or EAM systems with dubious data quality and they over-prescribed preventative maintenance.
- Plant technicians, while aware of asset issues through tribal knowledge (or via trial and error), didn't value good data hygiene. Reporting on actual work accomplished or findings in the field were poor.
- Plant operators had little visibility to what actual work was being completed on a daily basis and limited communication with technicians in the plant to coordinate work.
- Plant leadership was stuck in the middle trying to balance a budget handed down from headquarters while executing with less staff and more contractors than ever before.



Applying integrated digital solutions transforms these processes to develop a fully orchestrated maintenance strategy. Centralizing applications is critical. Otherwise, data ends up trapped in plant silos. The EAM systems remain essential to maintenance execution; APM tools are complementary as they focus on asset strategies and predictive analytics that define and prioritize the EAM work orders. New Asset Service Management (ASM) tools further support technician process.

Starting with the plant technician, ASM provides a single business process. Instead of needing to access separate apps or printers to get work orders, safety guidelines, and permits, or log out tag out, or review schematics, they can log in just once and have these workflows on their mobile devices. If questions are encountered on the job, chat, PTT or video sharing, contextualized by job and location, facilitate rapid cross-functional collaboration.

Simultaneously, the utility benefits from greater data inputs. The technician, empowered with access to the asset history, data analytics, alerts, cases, alarms, drawings and prior work orders, now clearly sees the value in the data and provides much better reporting.

Digital tools also help dig the centralized maintenance decision-makers out of the minutiae. APM uses analytics to prioritize what to work on and ASM allows for execution of weekly plans and complex maintenance, as well as quick response to critical, emergent work. The plant supervisors schedule work using APM to prioritize risk by ranking failure modes. These rankings are incorporated into the maintenance plan in the form of preventative, conditioned-based and corrective maintenance. The planned maintenance is then scheduled in ASM with a maintenance planner looking at a common scheduling platform to see prioritized work orders, available work crews (internal or contract) and their skill areas, and even safety and training needs.

Plant operators gain insight into what technicians are doing across the plant through ASM and its enhanced communication tools. If required, operational control of assets can be transferred to technicians for asset troubleshooting. Even plant operations can be completed remotely allowing for multi-plant control to improve how a utility operates its generation facilities.

These integrations provide fleet asset managers further insight into prioritized risk. Cycling decisions are made informed by data regarding mitigating damage. Improved maintenance strategies to improve reliability or reduce cost are also grounded in APM data and analytics. Pacing to actualize annual plans is significantly improved with added dashboards of ASM providing insight to what is actually happening at the plant.

This orchestrated maintenance strategy has implications for a utility's commercial teams as well. Commercial teams can now leverage asset information once isolated at the plant to make informed decisions regarding asset dispatch. Indeed, commercial teams can even be co-located with remote plant operators.

Prioritizing Assets to Capture End-of-Life Capabilities

Many vertically-integrated, regulated utilities are managing legacy assets while incorporating new solar and wind farms for generation, transmission and distribution. The breadth of the fleet requires managing plants with varying operating missions. Yet the utility wants to contain its maintenance costs and avoid introducing additional risk to operations.

Imagine a utility with a coal plant it plans to retire in the next seven to ten years. It wants to use up all its available performance before end-of-life. With synchronized OPM and APM, plant managers and maintenance planners can make data-informed decisions about whether or not to delay service.

OPM provides an economical way to run the asset. OPM Performance Intelligence looks at the overall system to see where degradation is happening and to what extent. OPM Production Planning helps the utility determine what generation is most economical to run and when. Analyzing APM data can also provide decision support for dispatch and asset managers looking to stack units. For instance, the remaining useful life modeling would help determine that the retiring coal plant could run at 60% until 2029 but at 80% until 2026.

APM also provides the economical way to do asset maintenance. Instead of having to react instantaneously when there is an issue, APM runs analyses to determine how much longer that asset can run reliably without causing damage or failure.

With Asset Service Management tools aligned with APM strategy, the utility can also see cost reductions from greater accountability and transparency with maintenance workers. Whereas in a traditional utility, there is no real-time tracking of the maintenance team and work order progress, this digital solution provides full visibility into who is doing what and where.

Digital Worker Digital Inspections tools and sensored devices can also provide more asset intelligence, no matter how remote the operations. Instead of relying on sending out technicians to take physical measurements or do visual inspections, the utility can gather useful data digitally, while freeing up its teams to do more preventive maintenance and keep the plant functioning at optimal levels.

Conclusions

Digital technologies provide ways to rethink operations and revisit revenue models. Taking advantage of interoperable IIoT solutions, power leaders gain access to data that can be effectively analyzed and acted upon to optimize operations, gain ecosystem insights, better understand and manage distribution, and streamline maintenance efforts.

GE's performance management applications provide:

- Digital Worker tools and technologies to improve business processes, manage O&M cost and schedule, and improve safety and quality
- APM Healthy & Reliability for asset health insights and predictive analytics to reduce unplanned downtimes
- APM Asset & Maintenance Optimization to balance availability, reliability, risk, and maintenance cost
- OPM Performance Intelligence for thermal performance analysis and advice to help achieve operating targets and improve business results
- OPM Production Planning to improve margins through capacity forecasting and decision support
- OPM Performance Optimization to safely expand capacity, efficiency, and flexibility while lowering emissions.

By examining the power of GE's APM, OPM, and Digital Worker offerings working in sync, this paper has highlighted specific areas where utilities can benefit from modular, interoperable IIoT solutions working together. Address today's fresh challenges and prepare for future industry pressures with digital innovation and the support of GE's experts.

Footnotes

1 Smith, S. 2019 Power and Utilities Industry Outlook. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-power-utilities-outlook-2019.pdf

2 Maloney, P. December 18, 2018. Moody's Sees Robust Utility Captital Spending in 2018, Dip in 2019, 2020. https://www.utilitydive.com/news/moodys-sees-robust-utility- capital-spending-in-2018-dip-in-2019-2020/544594/

3 Davinroy, H. October 1, 2018 Fix Smart: Digital O&M Can Improve LCOEs up to 6%.

4 IEEFA. March 6, 2019. Texas Grid Operator Warns of Tight Summer Electricity Supplies. http://ieefa.org/texas-grid-operator-warns-of-tight-summer-electricity-supplies/

5 Assume offers awarded 6 peak hours (hours ending 13 – 18); Houston Hub average RTM SPP for June ($57.74/MWh), July ($95.53/MWh), August ($70.70/MWh). June incremental revenue = $166k. July incremental revenue = $284k. August incremental revenue = $210k. Based on http://www.ercot.com/mktinfo/prices.

6 Assume 552 available hours for peak fire with out an additional maintenance impact; 6 hours per day in June, July and August; Houston Hub average RTM SPP for June ($57.74/ MWh), July ($95.53/MWh), August ($70.70/MWh), assuming hours ending 13 through 18. June incremental revenue = $177k. July incremental revenue = $302k. August incremental revenue = $224k. Based on http://www.ercot.com/mktinfo/prices.

7 Assume offers awarded 6 peak hours (hours ending 13 – 18); Houston Hub average RTM SPP for June ($57.74/MWh), July ($95.53/MWh), August ($70.70/MWh). June incremental revenue = $104k. July incremental revenue = $178k. August incremental revenue = $132k. Based on http://www.ercot.com/mktinfo/prices.

8 Assume 552 available hours for peak fire without an additional maintenance impact; 6 hours per day in June, July and August; Houston Hub highest 2208 (4x 552hours) RTM SPP 15 min intervals from March through June. March incremental revenue = $20k, 11.25 hrs. April incremental revenue = $69k, 50.5 hrs. May incremental revenue = $136k, 93.75 hrs. June incremental revenue = $138k, 99.5 hrs. July incremental revenue = $295k, 153.5 hrs. August incremental revenue = $210k, 143.5 hrs. Total revenue opportunity 868k – 703k = 165k. Based on http://www.ercot.com/mktinfo/prices.

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