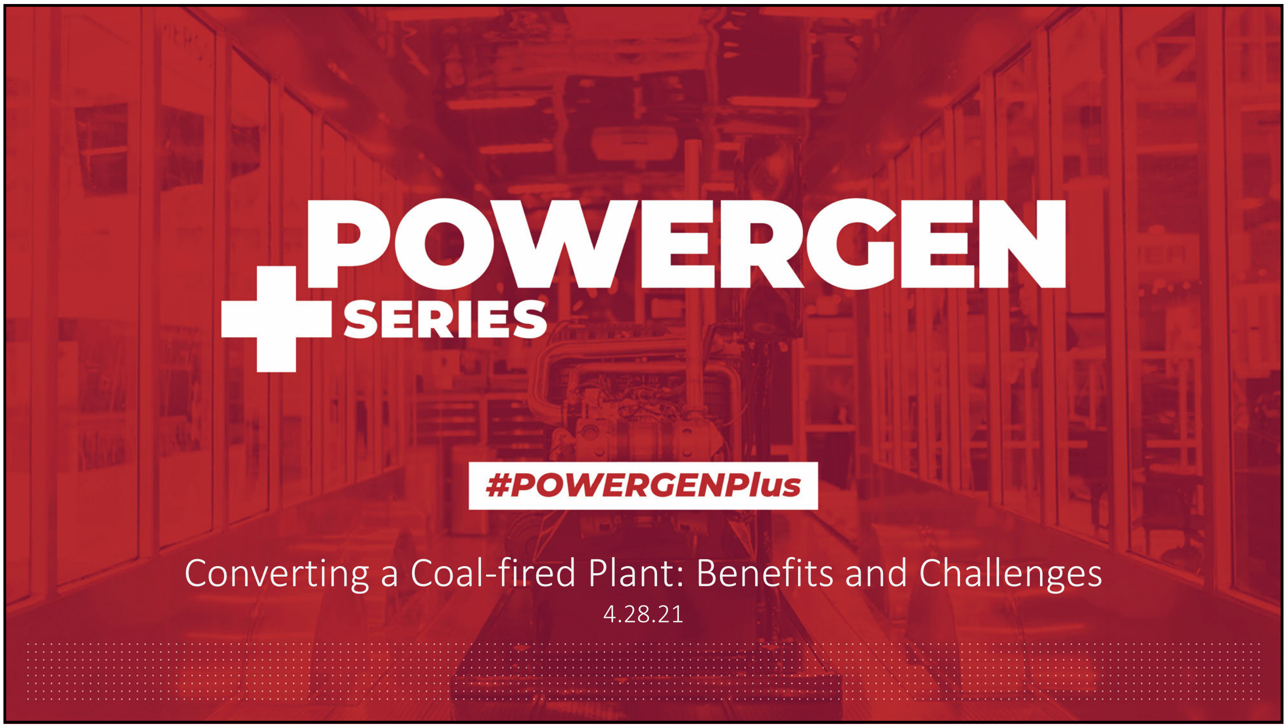
POWERGEN
SERIES
#POWERGENPlus
Converting a Coal-fired Plant: Benefits and Challenges
4.28.21

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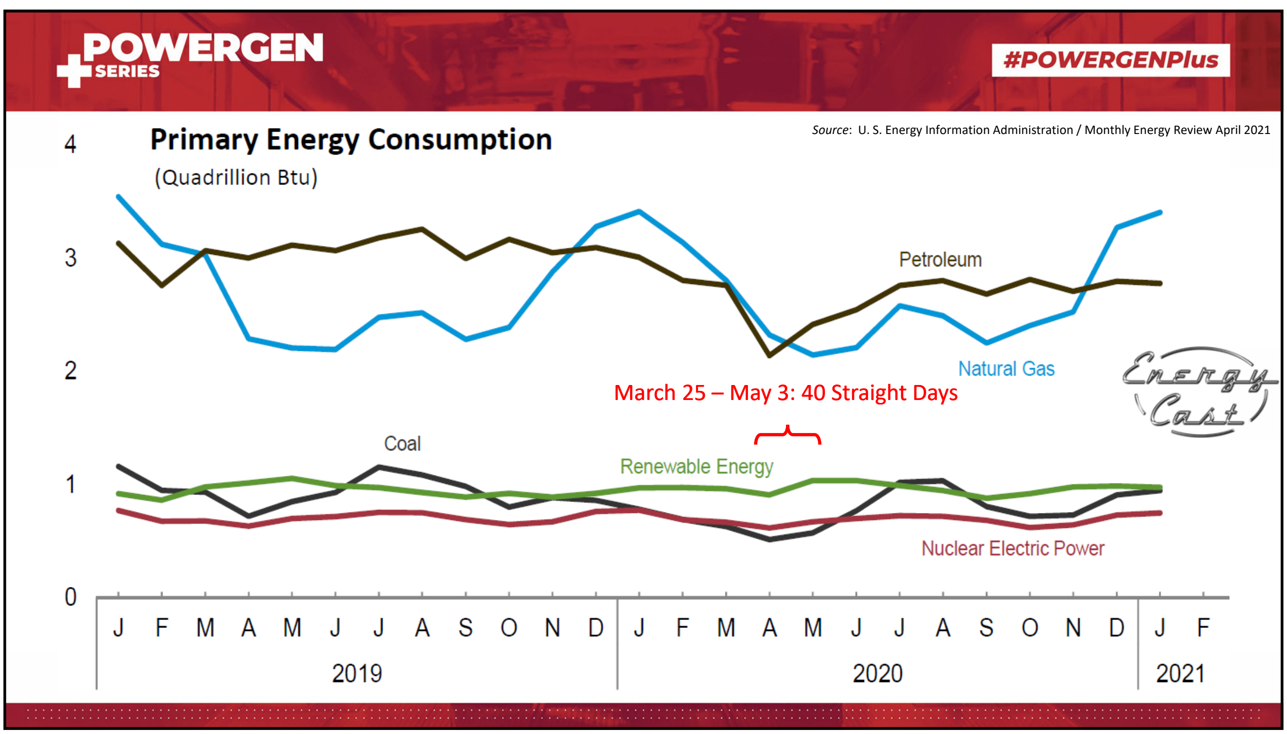
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Primary Energy Consumption
(Quadrillion Btu)
Source: U. S. Energy Information Administration / Monthly Energy Review April 2021
4
3
2
1
0
Petroleum
Natural Gas
March 25 – May 3: 40 Straight Days
Coal
Renewable Energy
Nuclear Electric Power
J F M A M J J A S O N D J F M A M J J A S O N D J F
2019
2020
2021
Energy Cast

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LOAD FOLLOWING – THE NEW NORMAL FOR U.S. COAL PLANTS?

POWERGEN+ April 28, 2021

Phillip Graeter

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ENERGY VENTURES ANALYSIS

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Introduction

- Energy Ventures Analysis is a consulting firm located in the Washington DC area, specializing in energy commodity market analysis since 1981
- In 2019/20, the National Association of Regulated Utility Commissioners (NARUC) hired EVA to develop a white paper on coal flexibility and reliability for state utility regulators
- EVA analyzed hourly operating data of U.S. coal plants for the years 2008, 2018, 2019, and 2020 to highlight trends in coal plant operations and recommend possible technologies and practices plant owners can adopt to increase a coal plant's flexibility, reliability, and profitability

ENERGY VENTURES ANALYSIS

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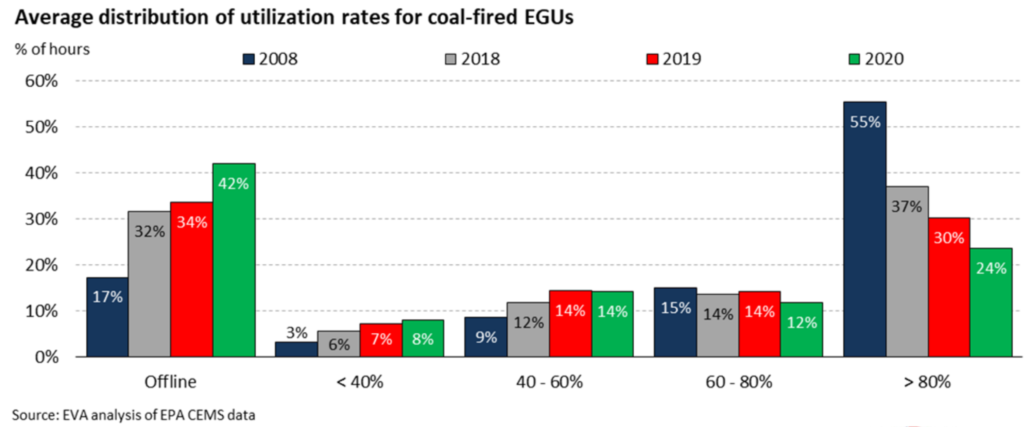
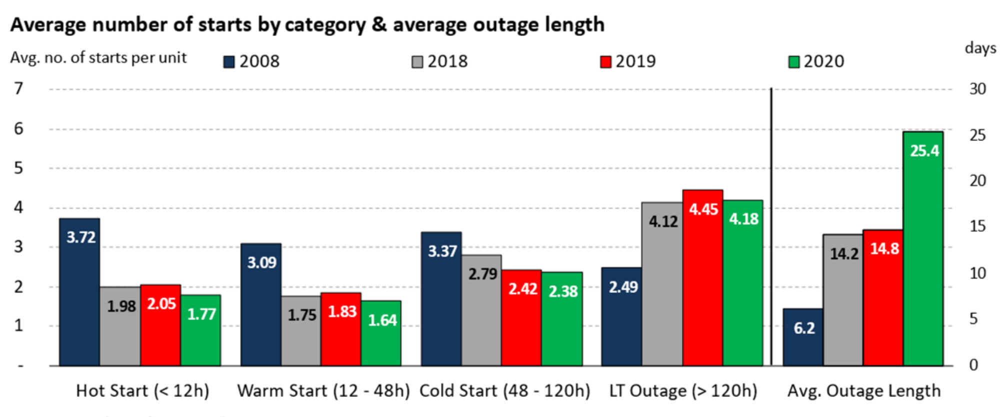
U.S. coal plants operate more and more at less optimal utilization rates



ENERGY VENTURES ANALYSIS

5

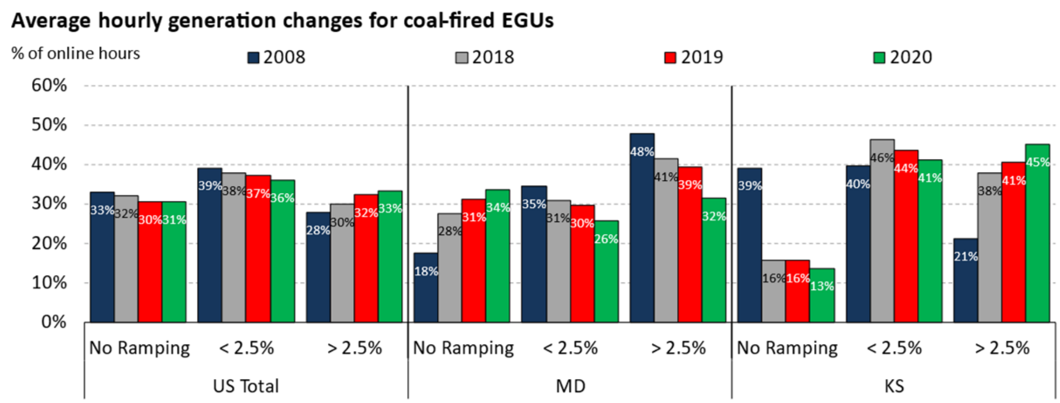
U.S. coal plants experience more starts at colder equipment temperatures & are offline much longer



ENERGY VENTURES ANALYSIS

6

Load changes at coal plants are much more frequent – but also depends on location



Source: EVA analysis of EPA CEMS data

ENERGY VENTURES ANALYSIS

7

Possible improvements to prepare coal plants for the new load-following reality

- **Cycling efficiency improvements**
  - Examples include sliding pressure operation, variable speed-drives, and boiler draft control schemes
- **Establishing and following cycle chemistry guidelines for flexible operations**
  - Correct layup procedures, combined with appropriate chemical treatment during shutdown and startup, will significantly reduce corrosion and deposits in the steam cycle equipment, including the boiler, steam-touched tubing, and the turbine
- **Accurate cycling cost estimation**
  - Helps inform plant’s true dispatch position based on operating costs
  - Cost estimates are based on increased routine maintenance costs, damage to major components, and estimated cost of consumables per start
- **Flexible operation studies**
  - These studies reduce component damage through procedure optimization and design modification
- **Data collection and operator coaching**
  - Plant data for critical components should be collected and screened to identify and understand the most damaging operational conditions
  - Simplified damage algorithms for creep and fatigue should be developed for operator coaching using collected data

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Coal Plant Conversions

Garry King

SVP, Global Services Leader, Power, Black & Veatch

BLACK & VEATCH

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Spectrum of Coal Plant Conversions

Fuel Switch to Natural Gas	Fuel Switch to Biomass	Partial Repower	Repower to Combined Cycle	Reuse Existing Site for new CC
Boiler and burner Modifications	Replace or modify boiler system	Add simple cycle gas turbine	Reuse steam turbine and…	Minimal reuse of support systems

Benefits vary depending on the situation:

- Life extension
- Higher plant output
- Increased efficiency
- Enhanced environmental performance
- Improved operability/maintainability

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Conversion Considerations

Technical and Financial:

- Fuel costs and price volatility
- Anticipated dispatch profiles
- Age and condition of plant equipment
- Capital costs, including gas pipeline
- Plant modification costs
- O&M costs, post-conversion

Non-Technical:

- Environmental
- Local acceptance
- Political
- Future regulations

A financially viable project can be derailed by non-technical issues.

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Keys to a Successful Repower

- Address social and regulatory matters early
- Strong collaboration between project participants
- Aim at future operating requirements and needs
- Realistic evaluation of current assets for reuse
- Thorough study before choosing a path
- Open model on economic trade-offs

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MHI KM CDR Process™

Post Combustion Carbon Capture Technology

Jerrad Thomas – Business Development Manager

MITSUBISHI HEAVY INDUSTRIES, LTD.

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Mitsubishi Heavy Industries Group at a Glance

As a global leader in engineering and manufacturing, Mitsubishi Heavy Industries (MHI) Group delivers innovative and integrated solutions across a wide range of industries from commercial aviation and transportation to power plants and gas turbines, and from machinery and infrastructure to integrated defense and space systems.

COMPANY HIGHLIGHTS		
$36.7BN Annual revenue	More than 24,600 Patents	54% Sales outside Japan
130 Years of Innovation	83,000 Employees worldwide	400+ Domestic & overseas companies

(FY2019 Results @110JPY/$)

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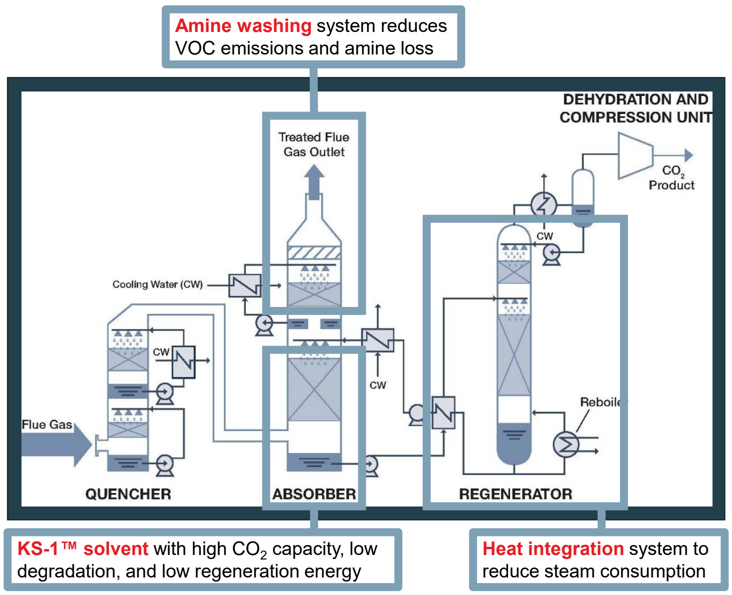
KM CDR Process™ Overview



- **KM CDR Process™** = *Kansai Mitsubishi Carbon Dioxide Recovery Process*
- Amine-based technology
- Capable of capturing ~95% CO_2 from combustion gas sources
- Proprietary features developed over 30 years of experience
- CO_2 purity >99.9% (dry basis)

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MHI's KM CDR Process™ Flue Gas Applications

The KM CDR™ Process has been applied to a variety of gases, and the effects of various impurities on the amine and the system have been tested.

Tested gases include:
- Natural gas-fired boiler exhaust
- Oil-fired boiler exhaust
- Coal-fired boiler exhaust
- Gas turbine exhaust (simulated)

Industrial applications:
- Power plants (NGCC, coal-fired, or biomass)
- Steam methane reformer furnace exhaust
- Cement plants
- Steel plants
- Catalytic crackers
- Natural gas processing

Typical Flue Gas Conditions

	Unit	Coal fired Boiler	NG fired GT	NG fired Boiler
CO_2	Vol.%	10 - 14	3 - 4	8 - 9
O_2	Vol.%	4 - 6	10 - 15	1 - 2
SOx	ppm(dry)	1 - 50	<0.3	<1
PM (Dust)	mg/Nm^3	3 - 10	NA	NA

Other possible constituents in the flue gas depending on the industrial application:
- NOx
- CO
- H_2S
- Hydrocarbons
- Heavy metals
- Halides (HCl, HBr, HF)

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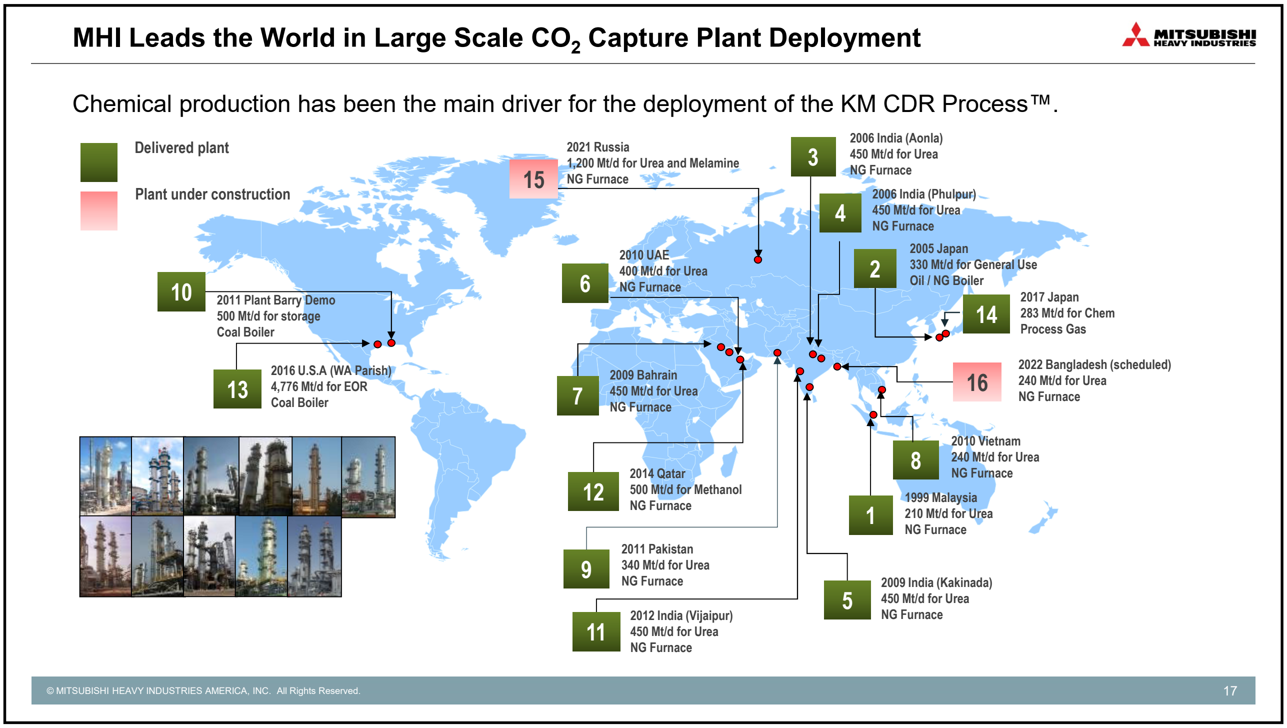
MHI Leads the World in Large Scale CO_2 Capture Plant Deployment
MITSUBISHI HEAVY INDUSTRIES
Chemical production has been the main driver for the deployment of the KM CDR Process™.
Delivered plant
Plant under construction
15 2021 Russia 1,200 Mt/d for Urea and Melamine NG Furnace
3 2006 India (Aonla) 450 Mt/d for Urea NG Furnace
4 2006 India (Phulpur) 450 Mt/d for Urea NG Furnace
2 2005 Japan 330 Mt/d for General Use Oil / NG Boiler
14 2017 Japan 283 Mt/d for Chem Process Gas
16 2022 Bangladesh (scheduled) 240 Mt/d for Urea NG Furnace
8 2010 Vietnam 240 Mt/d for Urea NG Furnace
1 1999 Malaysia 210 Mt/d for Urea NG Furnace
5 2009 India (Kakinada) 450 Mt/d for Urea NG Furnace
11 2012 India (Vijaipur) 450 Mt/d for Urea NG Furnace
9 2011 Pakistan 340 Mt/d for Urea NG Furnace
12 2014 Qatar 500 Mt/d for Methanol NG Furnace
7 2009 Bahrain 450 Mt/d for Urea NG Furnace
6 2010 UAE 400 Mt/d for Urea NG Furnace
10 2011 Plant Barry Demo 500 Mt/d for storage Coal Boiler
13 2016 U.S.A (WA Parish) 4,776 Mt/d for EOR Coal Boiler
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