GEMS 2024

Unit 11 Plant Upgrades for NGID Capacity Expansion

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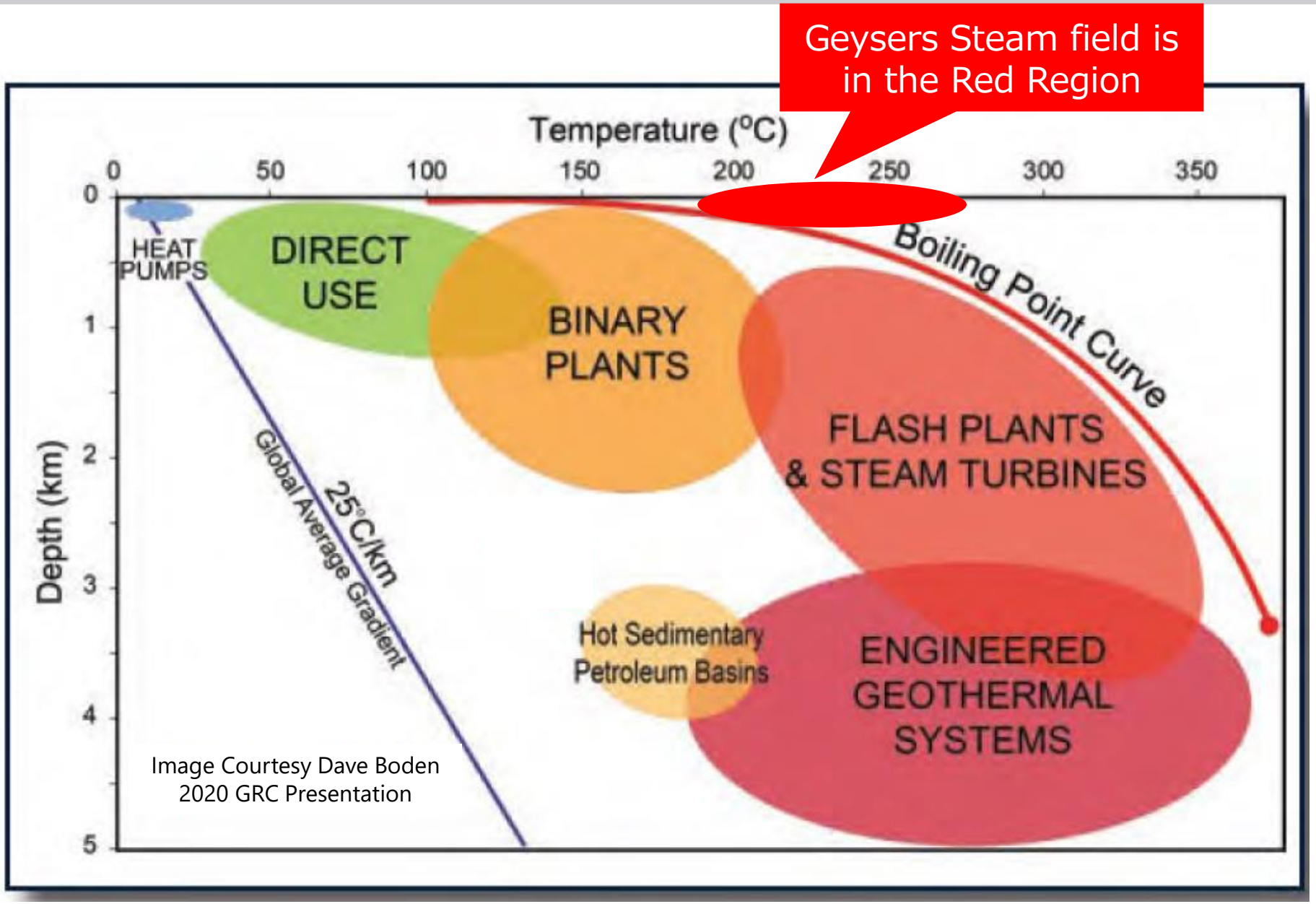
Agenda

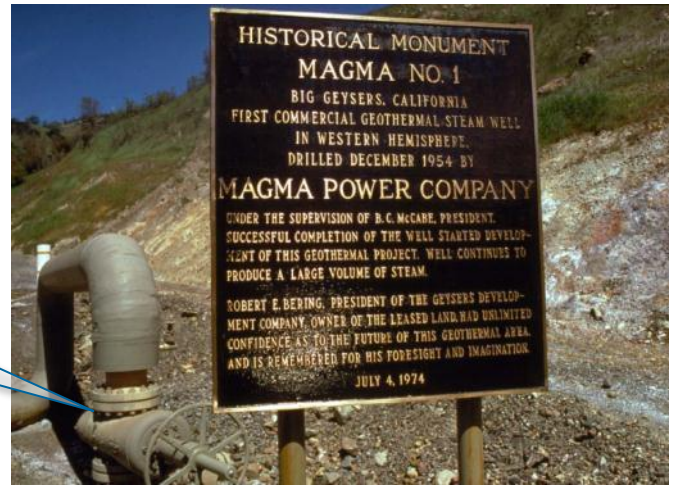
- Superheated Steam!
- Plant Construction & History
- Facility Overview
- Wellfield Expansion
- Process Modeling
- Plant Equipment Upgrades
- Toshiba in Geothermal
- Toshiba & Calpine's Partnership
- Technology Innovation & Implementation
- Come Visit The Geysers!

Types of Geothermal Systems and Related Power Plants



Development Starts, 1950's - Drilling

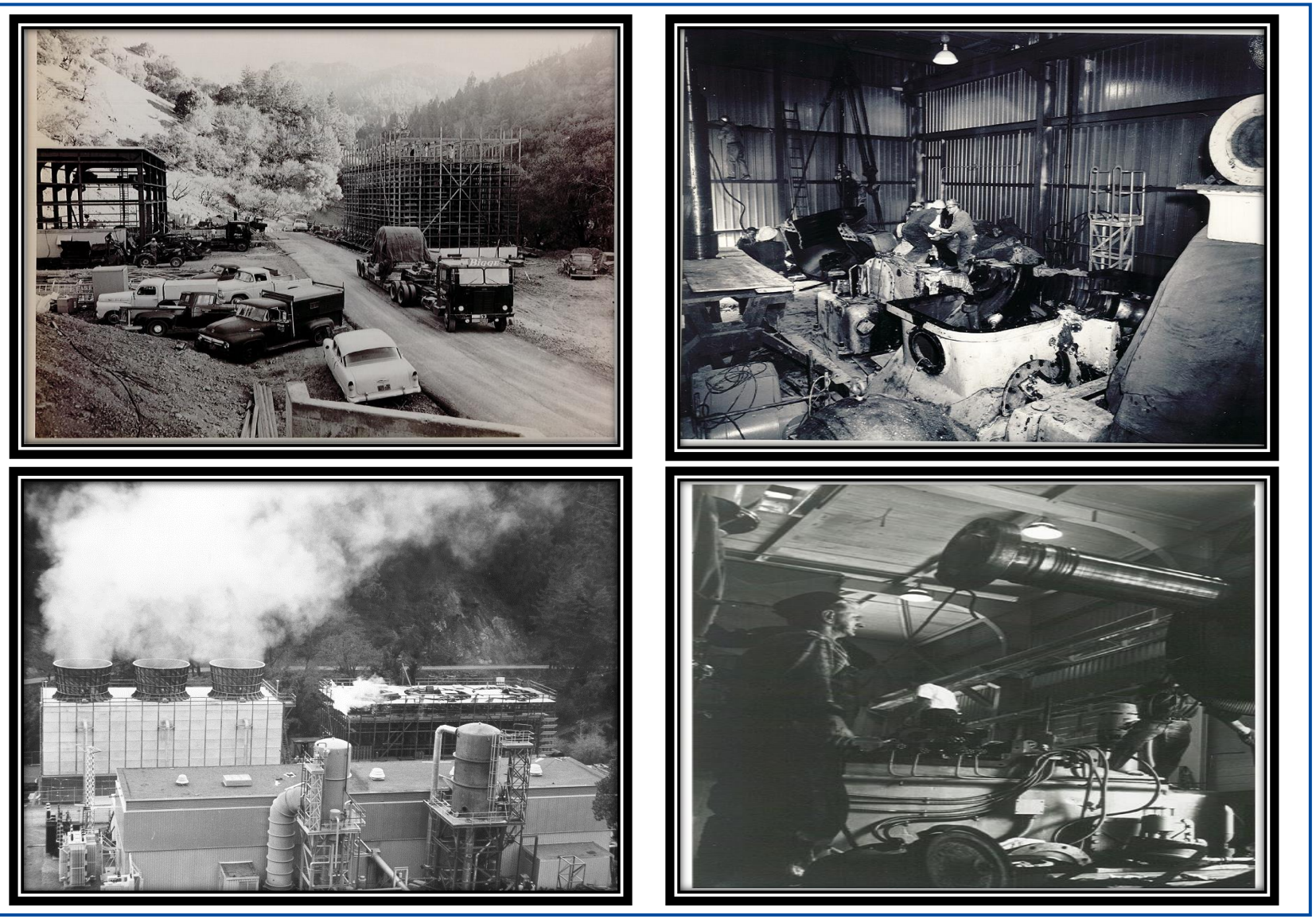
First modern well drilled in 1955 – still producing today!



6-month(!) flow test.

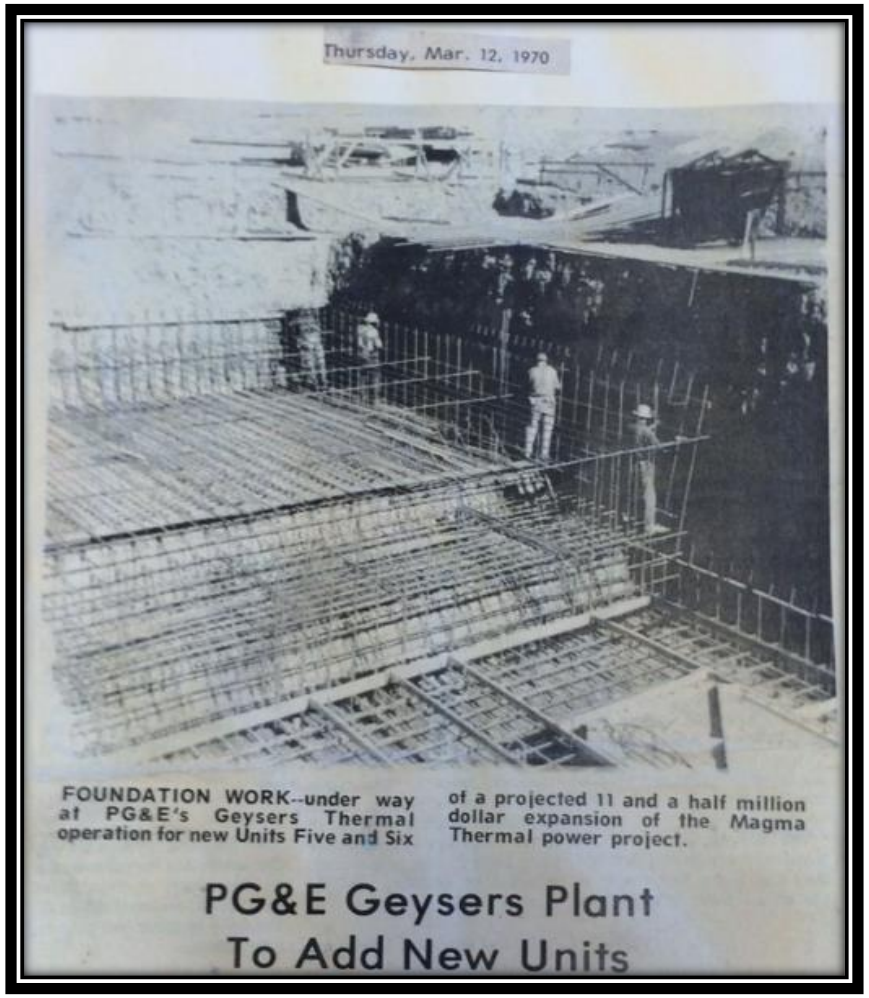
Developers convince PG&E…

Plant Construction, COD 1960-89



U1&2, 1960-63, 12 & 14 MW_{gross}

Plant Construction, COD 1960-89



Thursday, Mar. 12, 1970

FOUNDATION WORK--under way at PG&E's Geysers Thermal operation for new Units Five and Six of a projected 11 and a half million dollar expansion of the Magma Thermal power project.

PG&E Geysers Plant To Add New Units

MILLWRIGHTS are shown here connecting a generator and turbine at Units 5 and 6. Facing the camera and swinging the sledge is Gene Evans, Sacramento Local 1051. Back to camera is Jim James, Oakland Local 102. Roy McCormack, Local 102, is Millwright foreman, running the job for Peter Kiewitt Sons.

U5&6, 1971, 55 MW_{gross} each, 2-flow

Plant Construction, COD 1960-89

U12, 1979, 110 MW_{gross}, 4-flow

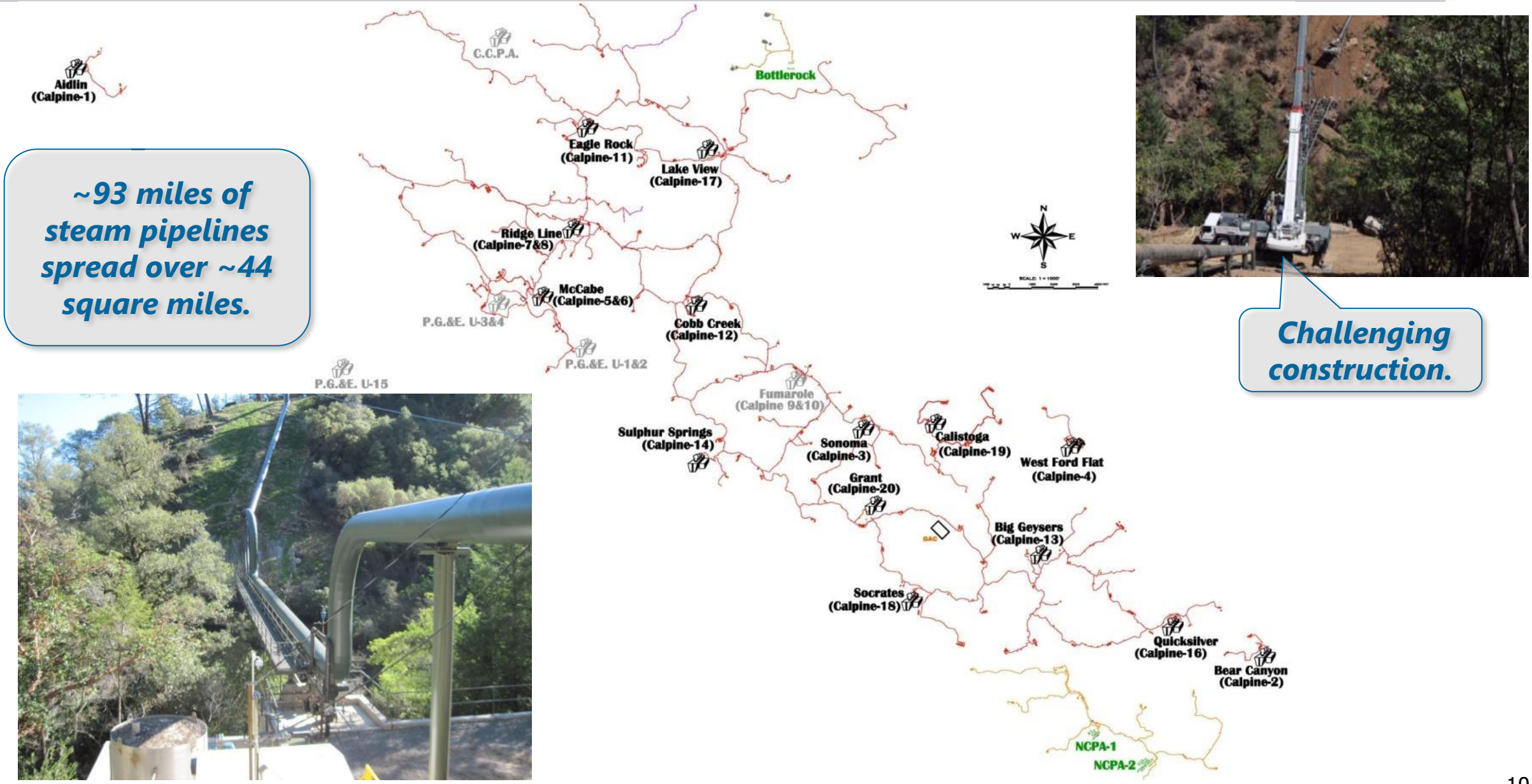
Plant Construction, COD 1960-89

U14, 1980, 114 MW_{gross}, 4-flow

The Geysers, Calpine Facility Overview

725 MWnet Capacity

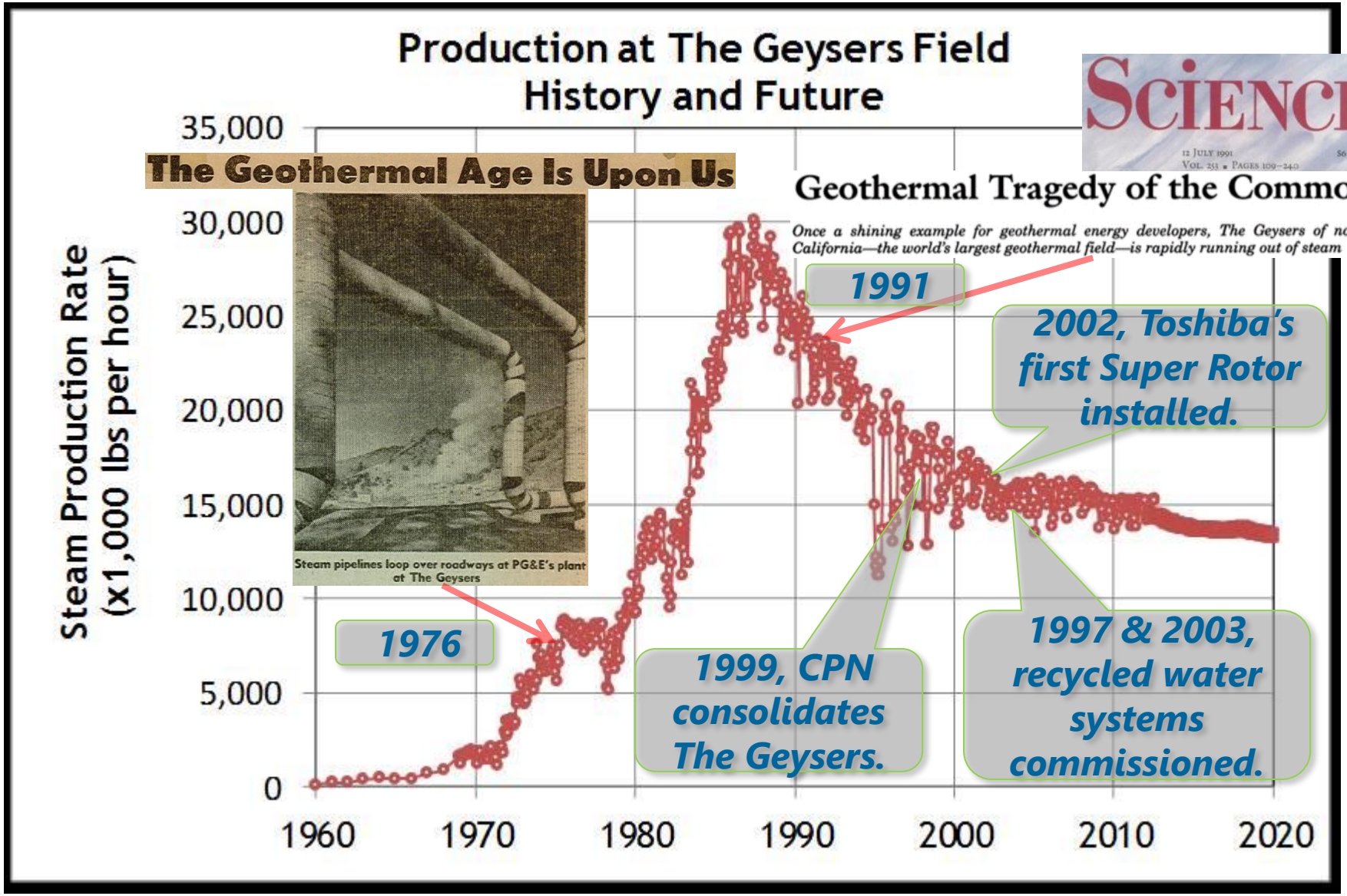
Steamfield Overview



~93 miles of steam pipelines spread over ~44 square miles.

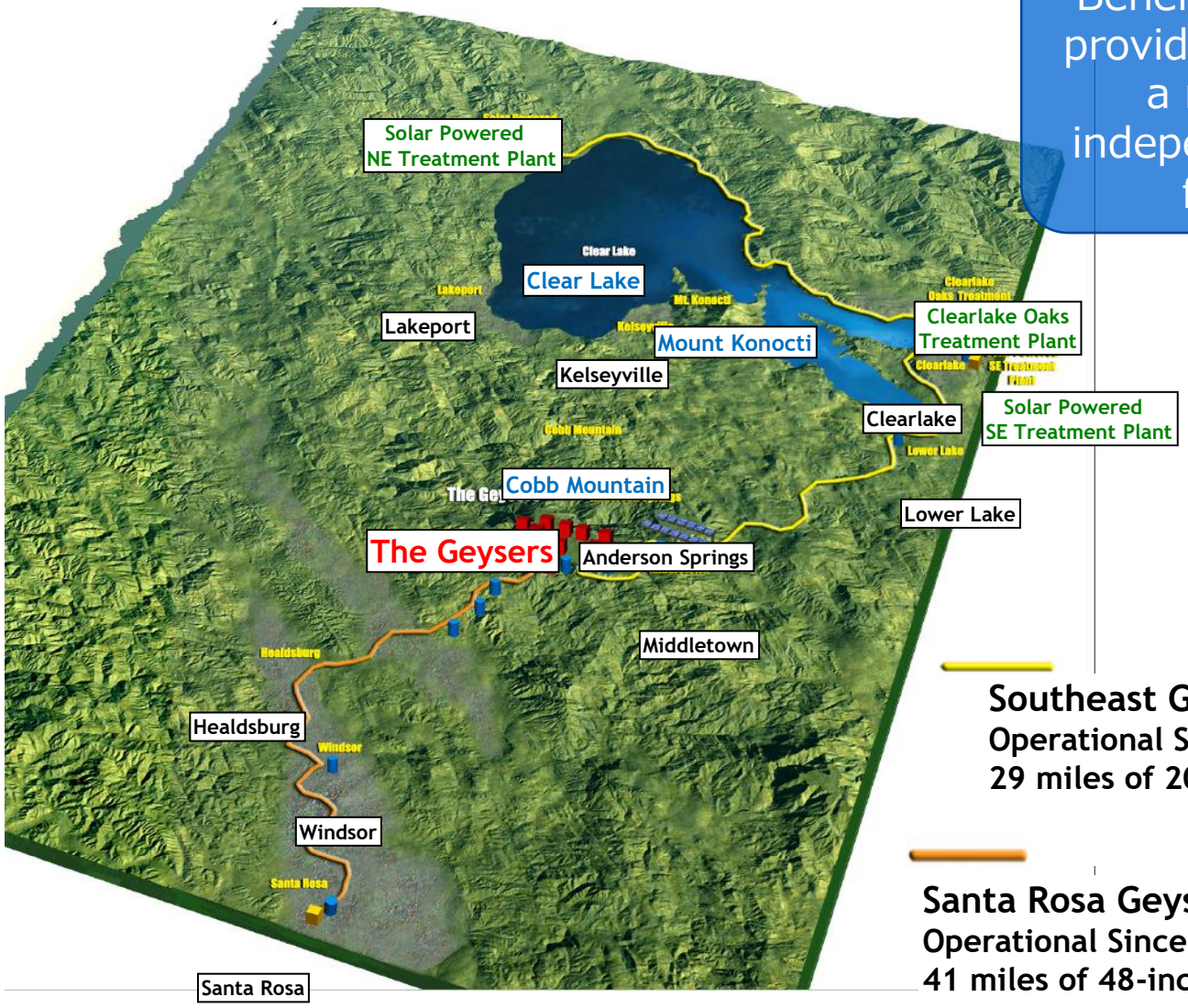
Challenging construction.

Steam Field Production Over Time



Source: EPRI Report, **"Next Generation Geothermal Power Plants,** *2012 Update*"

The Geysers – Recycled Water Projects



Benefiting The Geysers while providing nearby communities a responsible weather independent disposal method for recycled water.

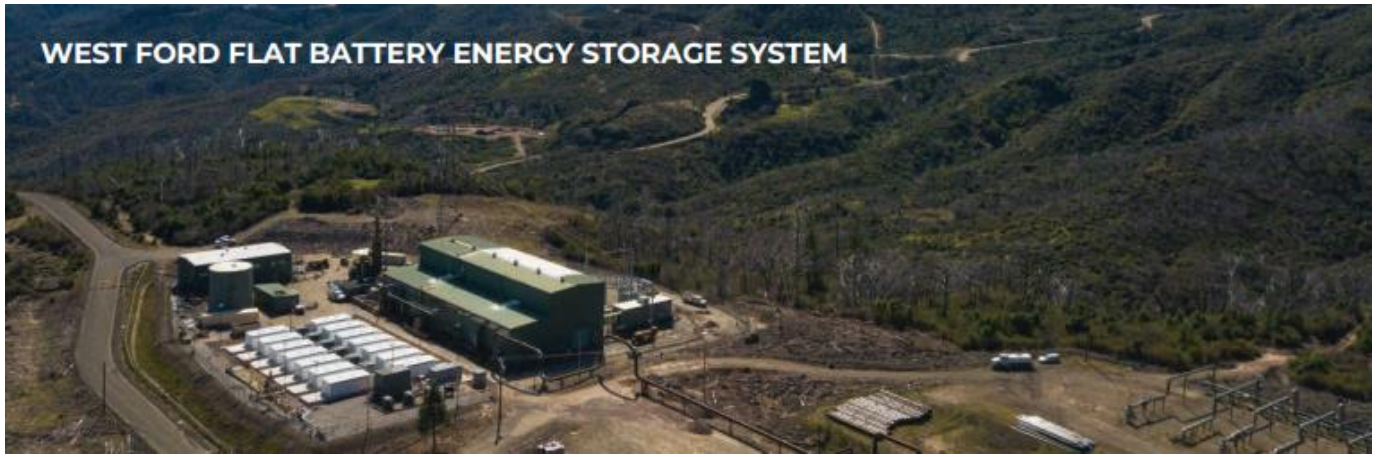
- Pump Station
- Treatment Plant
- Power Plant
- Solar Panels

Southeast Geysers Effluent Pipeline
Operational Since 1997
29 miles of 20-inch pipeline

Santa Rosa Geysers Recharge Project
Operational Since 2003
41 miles of 48-inch pipeline

Geothermal Resurgence & Geysers Expansion

- Regulatory Initiatives
  - CPUC mandate for 1 GW of geothermal/biomass power generation
  - DOE grant programs focusing on geothermal development
  - Renewal Portfolio Standards programs expanding across the US - markets suggest a need for baseload power to balance wind and solar variability
- Geyser's expansion opportunities to meet grid reliability requirements
  - North Geysers Incremental Development project
    - Initial phase will use incremental steam from new well drilling
      - Steam will be delivered to existing facilities including U11 and U17
      - U11 super rotor project will be designed around new steam conditions
    - Additional expansion opportunities in the North Geysers being evaluated
  - Recently installed 38 MW of 4 hour battery storage

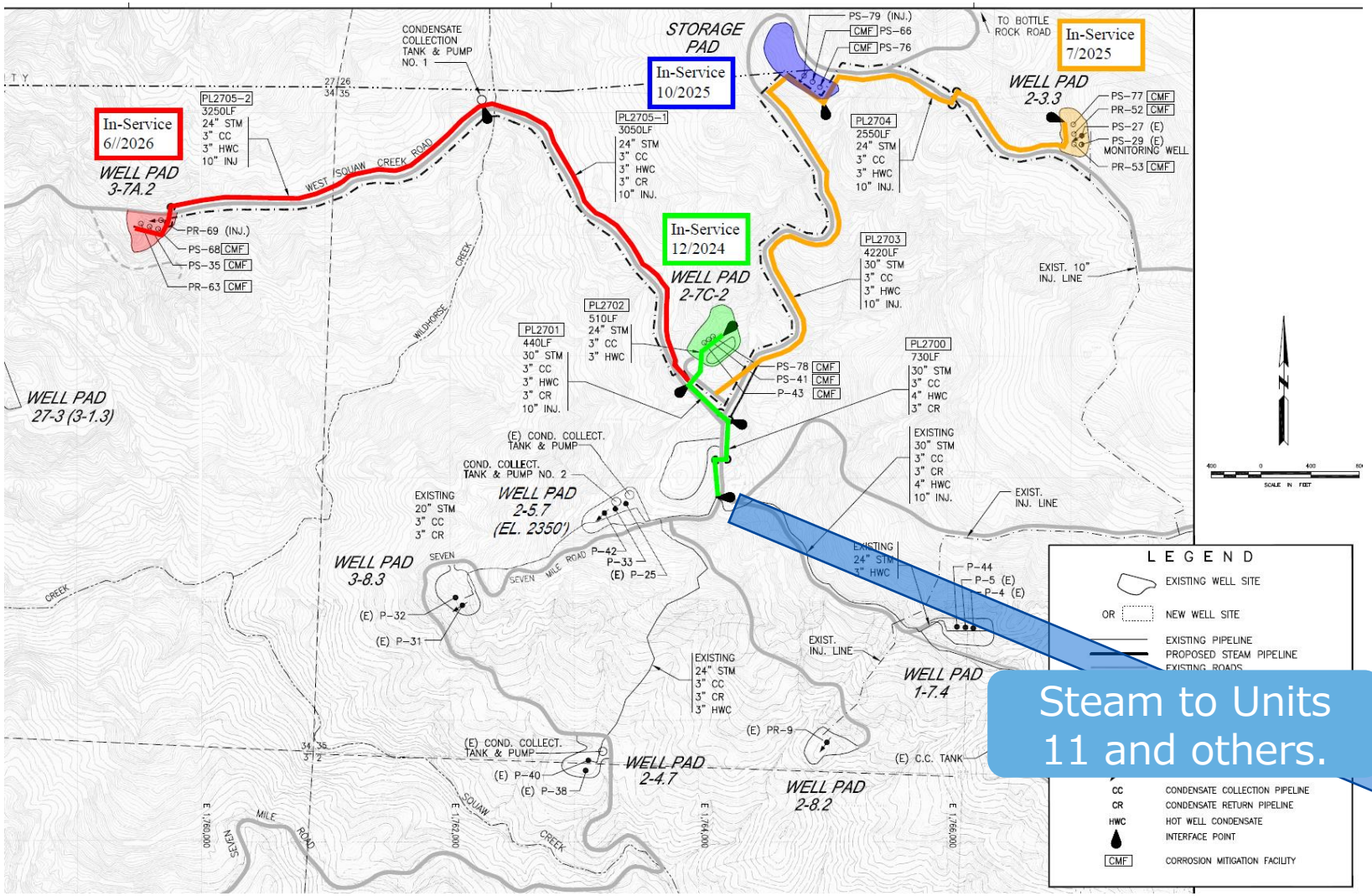


North Geysers Incremental Development

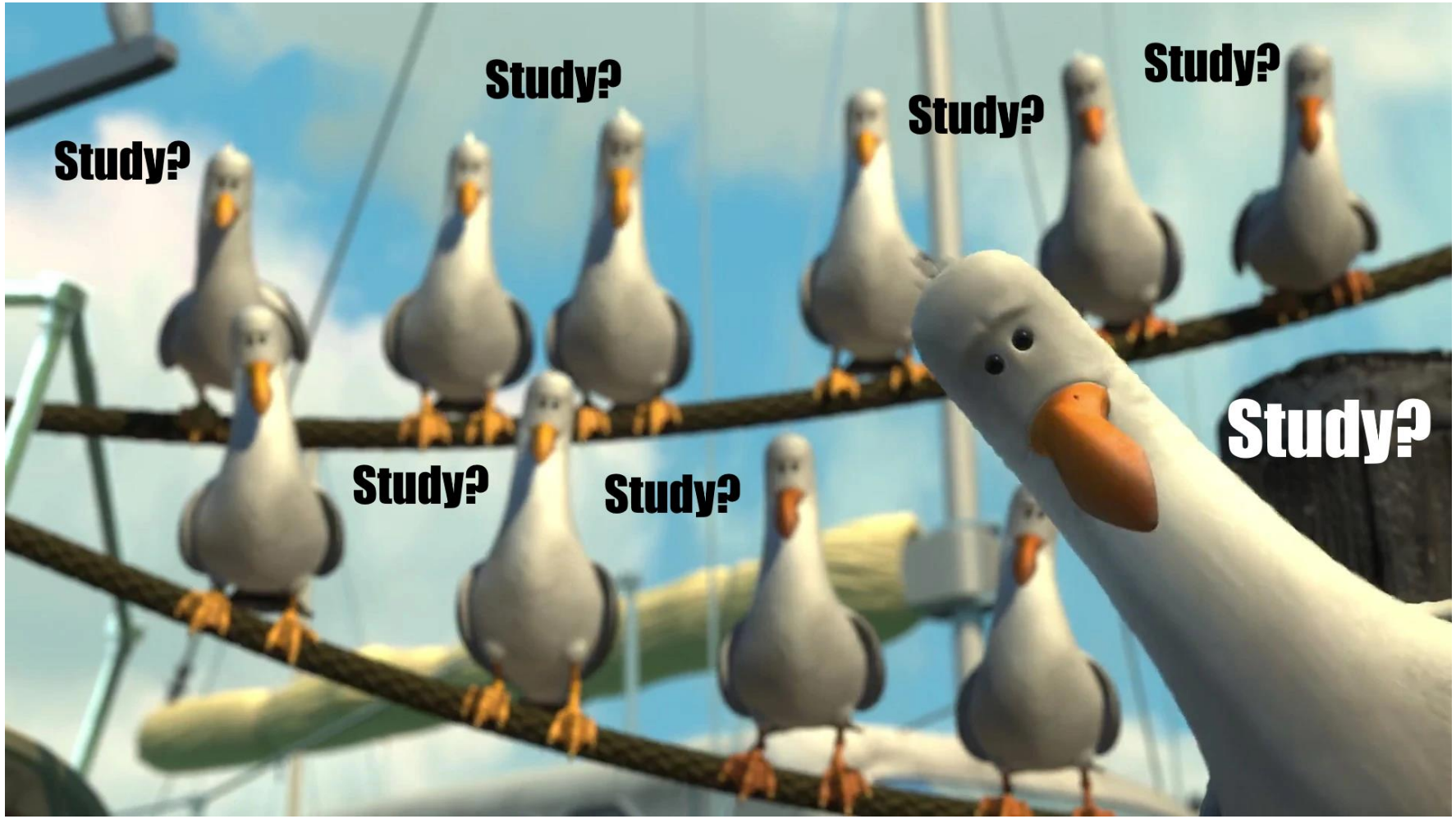
Overview

Owner	Geysers Power Company, LLC
Size	25 MW
COD	6/01/2025 - 6/01/2026
Technology	Existing Turbines
Construction	GPC Projects Team
Offtake	7 MW and 18 MW 20-YR PPA's
Interconnection	Existing LGIA
Use Permit	Sonoma County

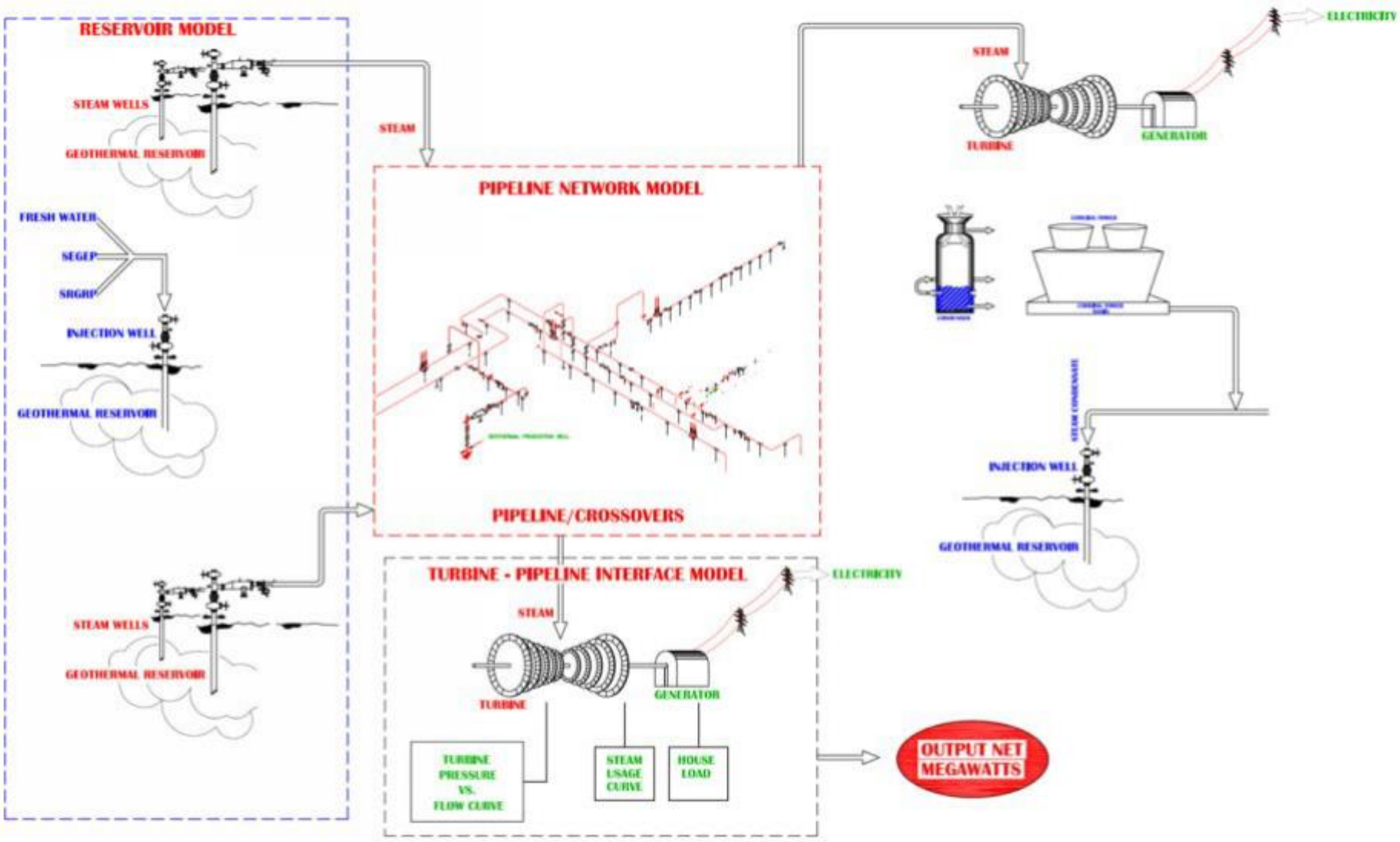
PS-41 Wellhead



First Things First



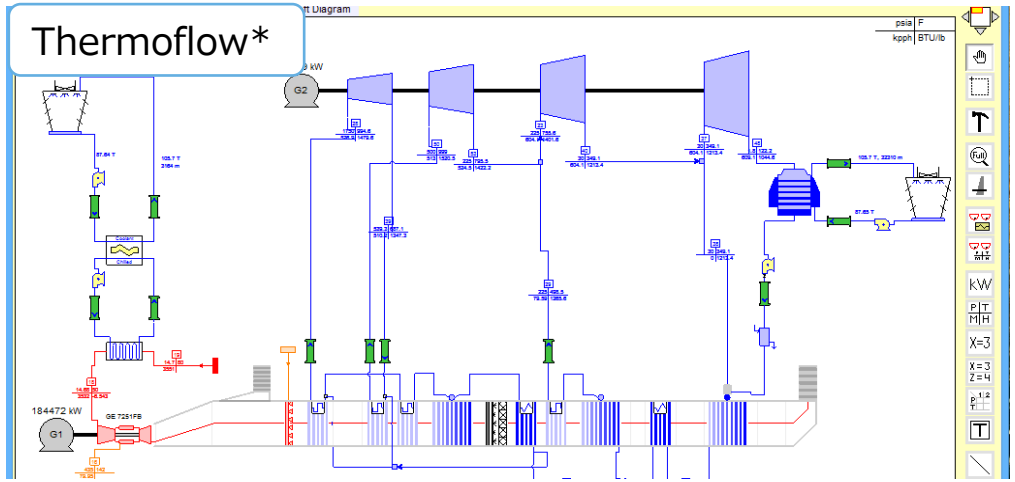
Integrated Models



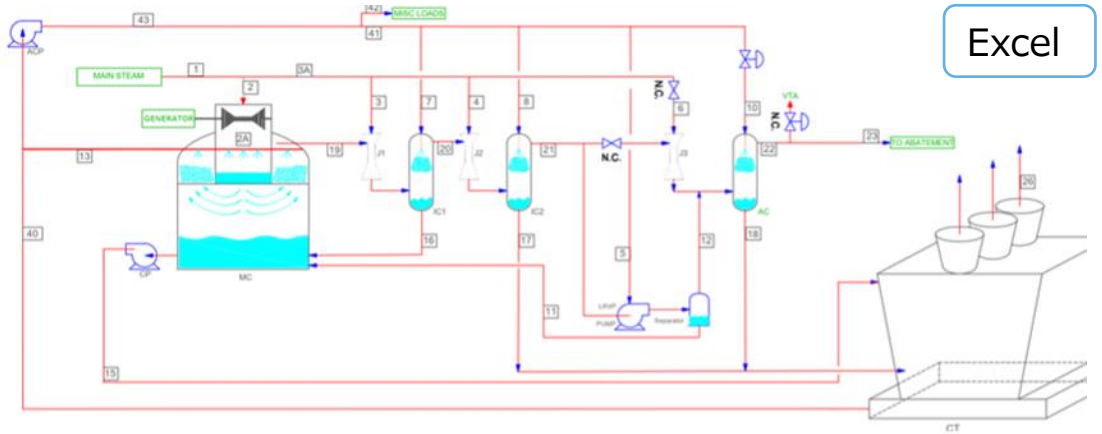
Power Plant Model Options

Replacing legacy GateCycle plant models

Thermoflow*

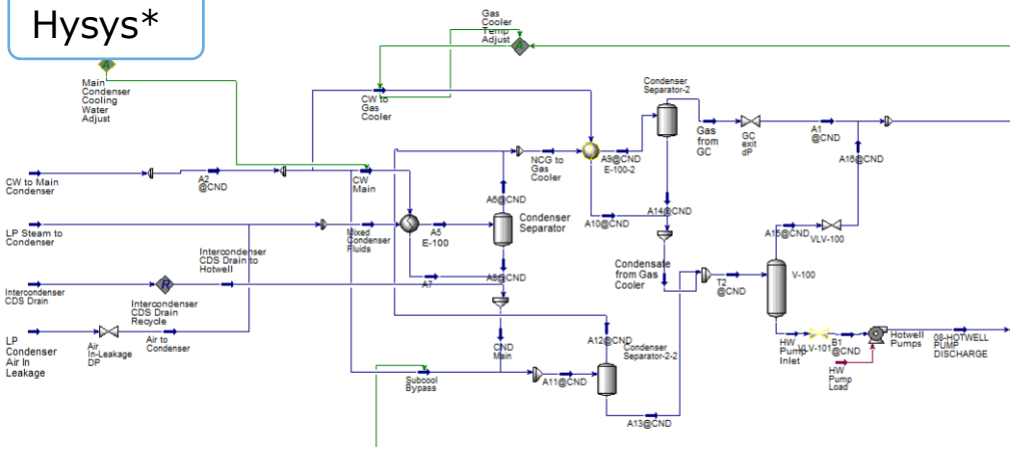


Excel

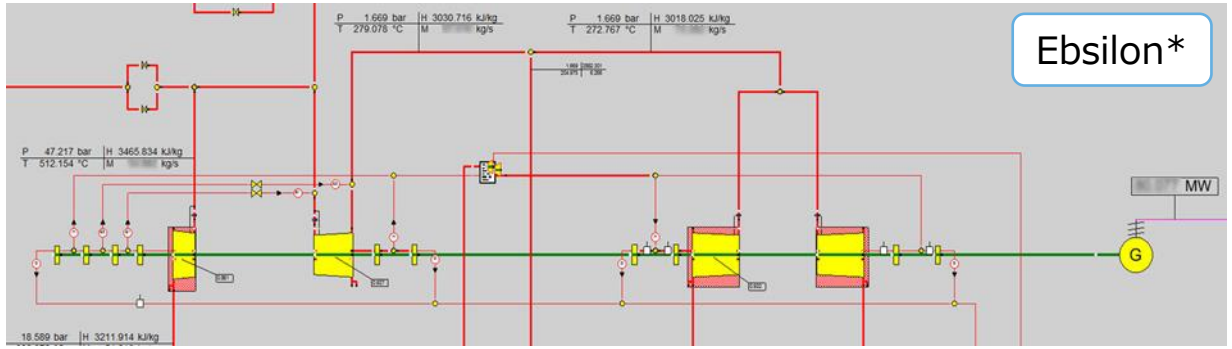


Property	Units	Plant Steam	Turbine Steam	Turb. Exhaust/	Total Motive	Motive Steam to	Motive Steam to	ACW to LRVPs	Motive Steam to	IC1 ACW In	IC2 ACW In	AC ACW In
		1	2	2A	3A	3	4	5	6	7	8	10
Total Mass Flow	lb/hr											
Vapor flow	lb/hr											

Hysys*



Ebsilon*



**Note: Examples only - not actual Calpine plant models*

Objectives

Jacobs

Proof of concept: Will it work?

Immediate need: Unit 11 super rotor

Medium-term goal: Full fleet 2025 forecasting

Next upgrade: Unit 5 super rotor selection

Future work – Transition to Ebsilon

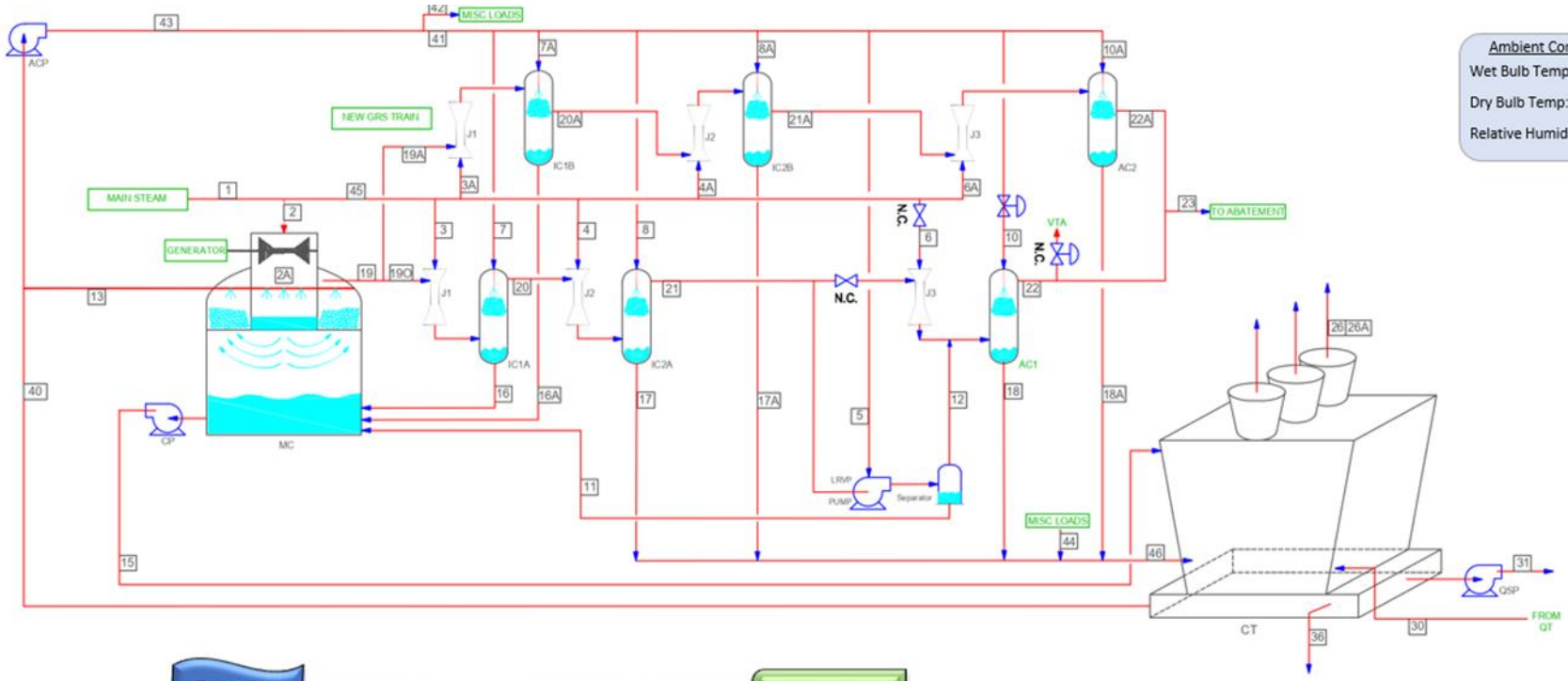
Unit 11 Model

Plant/Unit:	Unit 11
PLANT INPUT CONDITIONS [Stream 1]	
Plant Steam Flow	lb/hr
Use Future Well Deliverability Curve	
Steam Pressure	psig
Steam Superheat	1.00 °F
Steam Temperature	329.6 °F
Motive Steam Pressure	70 psig
Gas Content	0.6% wt %
Ambient Wet Bulb	55.0 °F
Ambient Dry Bulb	65 °F
Ambient Pressure	13.5 psia
Condenser Water Flow Rate	81,430 gpm
Condensate Pumps OOS (4 total	0
CT Fans OOS (9 total)	0
Use New CT?	Yes
Which Rotor?	GRM26SS

User Input Cell

RESULTS	
Plant Gross Power	kWe
Plant Total Aux Power	kWe
Cooling Tower Fans	*kWe*
Condensate Pumps	*kWe*
ACWP	*kWe*
LRVPs	*kWe*
Misc Aux Load	*kWe*
Plant Net Power	kWe

Useful Metrics/KPIs		
Turbine Steam Rate		lb/kW-hr
Plant Volumetric Flow		MMcfh
Plant Carnot Efficiency		
Turbine Exit Quality		
Condenser Pressure		inHgA



Ambient Conditions		
Wet Bulb Temp:	55.0	°F
Dry Bulb Temp:	65	°F
Relative Humidity:	54.3%	

Generate TBC

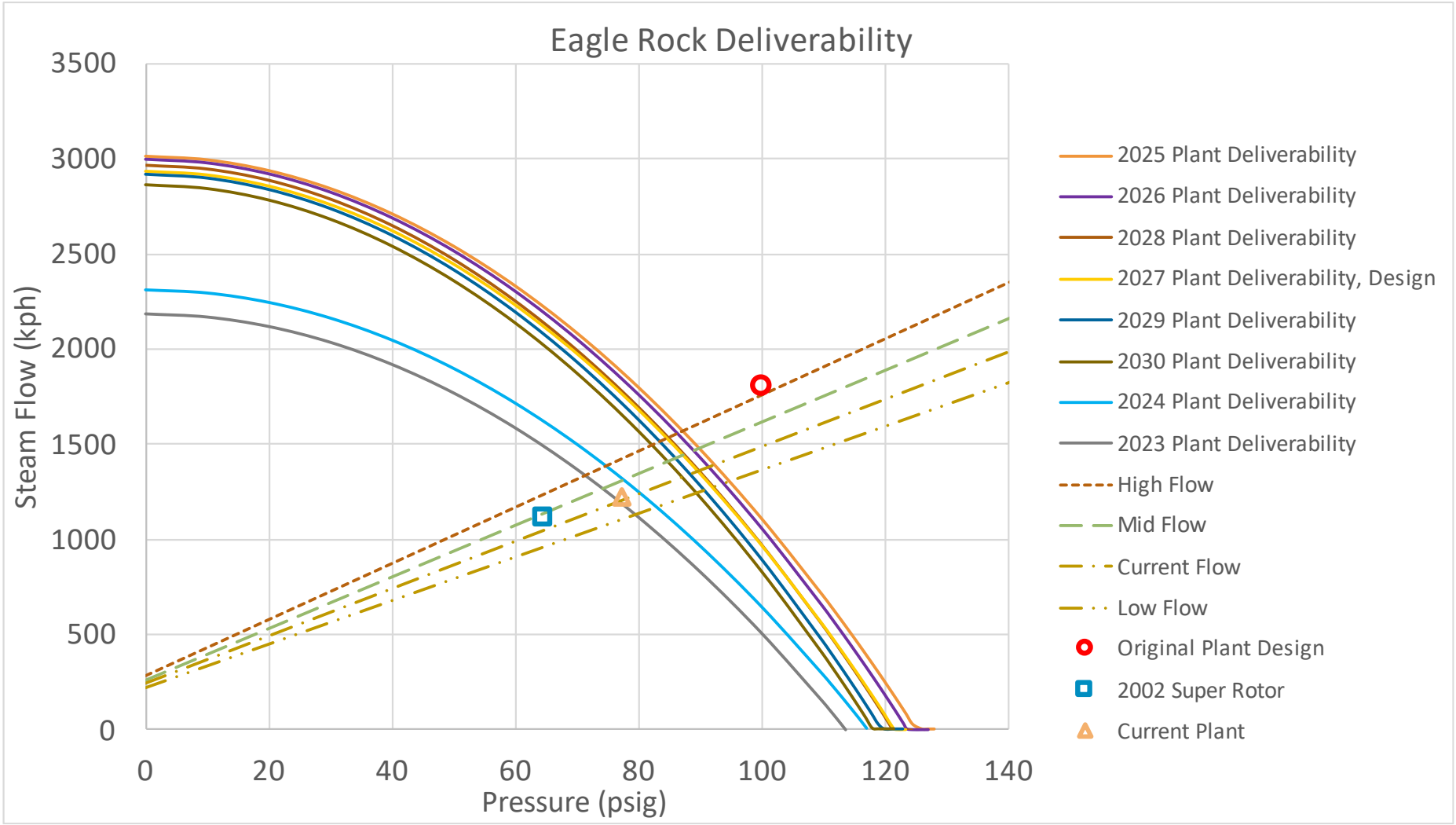
TBC Case:
Complete

# of Loops:	Status
4	Complete

Run Model

Property	Variable Name	Units	Plant Steam Inlet	Turbine Steam Inlet	Turb. Exhaust/ Cond. Inlet	Motive Steam to 1st Stage	Motive Steam to 1st Stage (New)	Motive Steam to 2nd Stage	Motive Steam to 2nd Stage (New)	ACW to LRVPs	Motive Steam to 3rd Stage	Motive Steam to 3rd Stage (New)	IC1A ACW In	IC1B ACW In (New)	IC2A ACW In	IC2B ACW In (New)	AC1 ACW In
Stream ID			PSS	TSS	CON	MS1	MS1A	MS2	MS2A	LRS	MS3	MS3A	I1S	I1SA	I2S	I2SA	ACS
Stream Number			1	2	2A	3	3A	4	4A	5	6	6A	7	7A	8	8A	10
Total Mass Flow	M_tot	lb/hr															
Vapor flow	M_v	lb/hr															
Gas flow	M_g	lb/hr															
Volumetric Flow	Q	gpm															
Pressure	-	psig															
Pressure	P	psia															

Super Rotor Selection



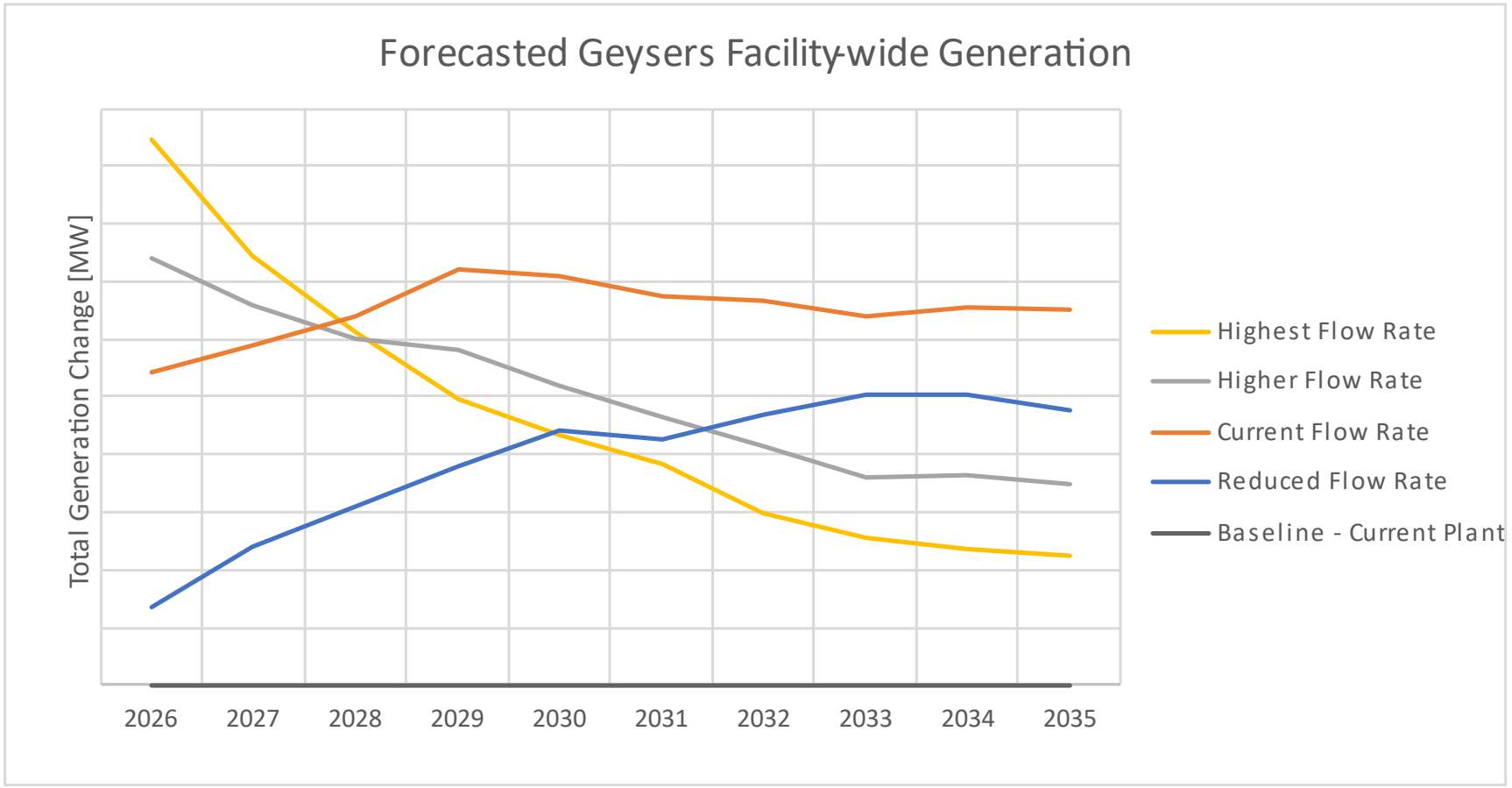
Evaluation Factors

Net Generation	OPEX	Others
• Maximizing generation of the entire Geysers Facility	• Secondary abatement chemicals (scale linearly with steam flow)	• Impacts to Balance of Plant systems due to increased flows

Challenges:

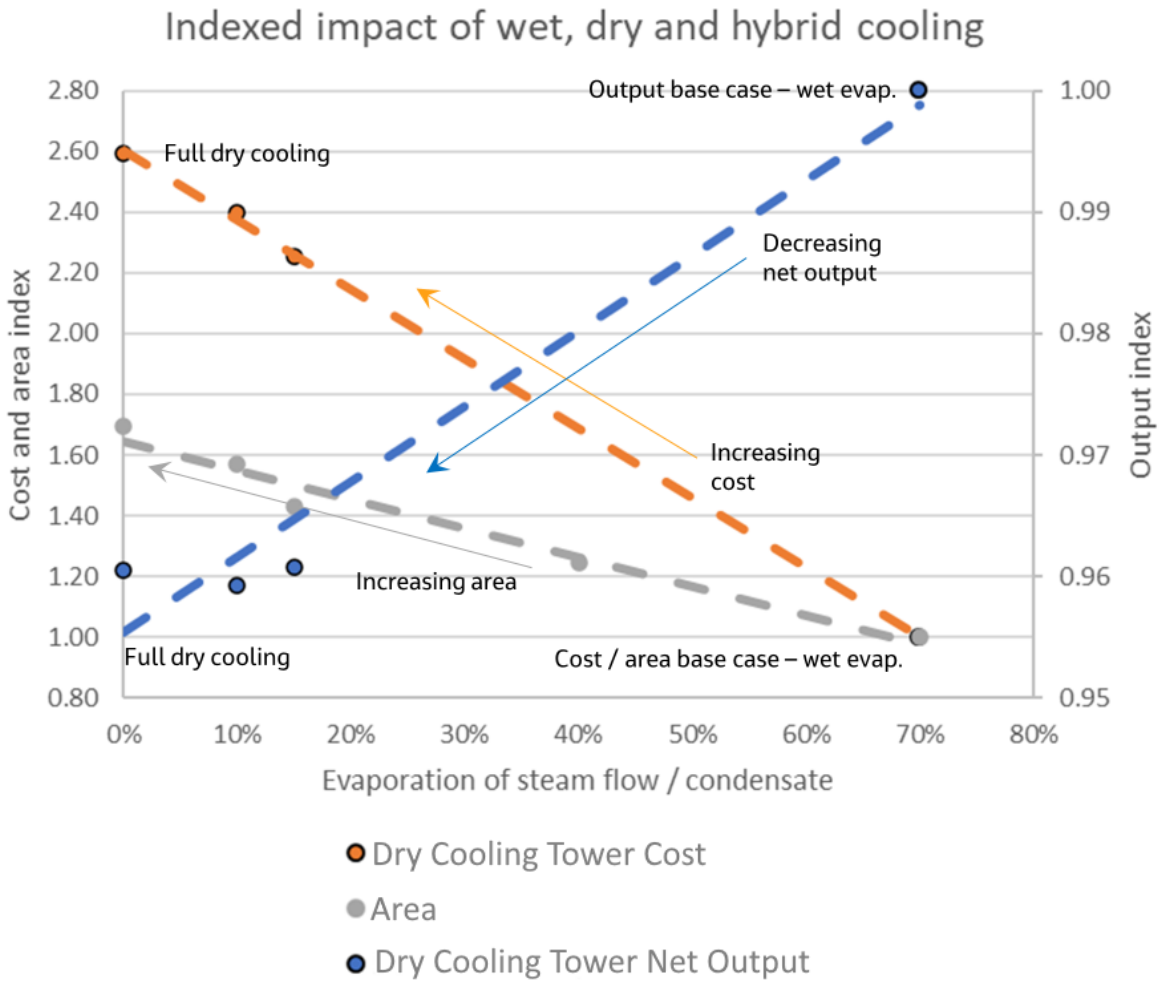
- Isolating impacts of individual upgrade projects, including upgraded Cooling Tower and Condenser/GRS
- Forecasting changes over time for 10-yr period

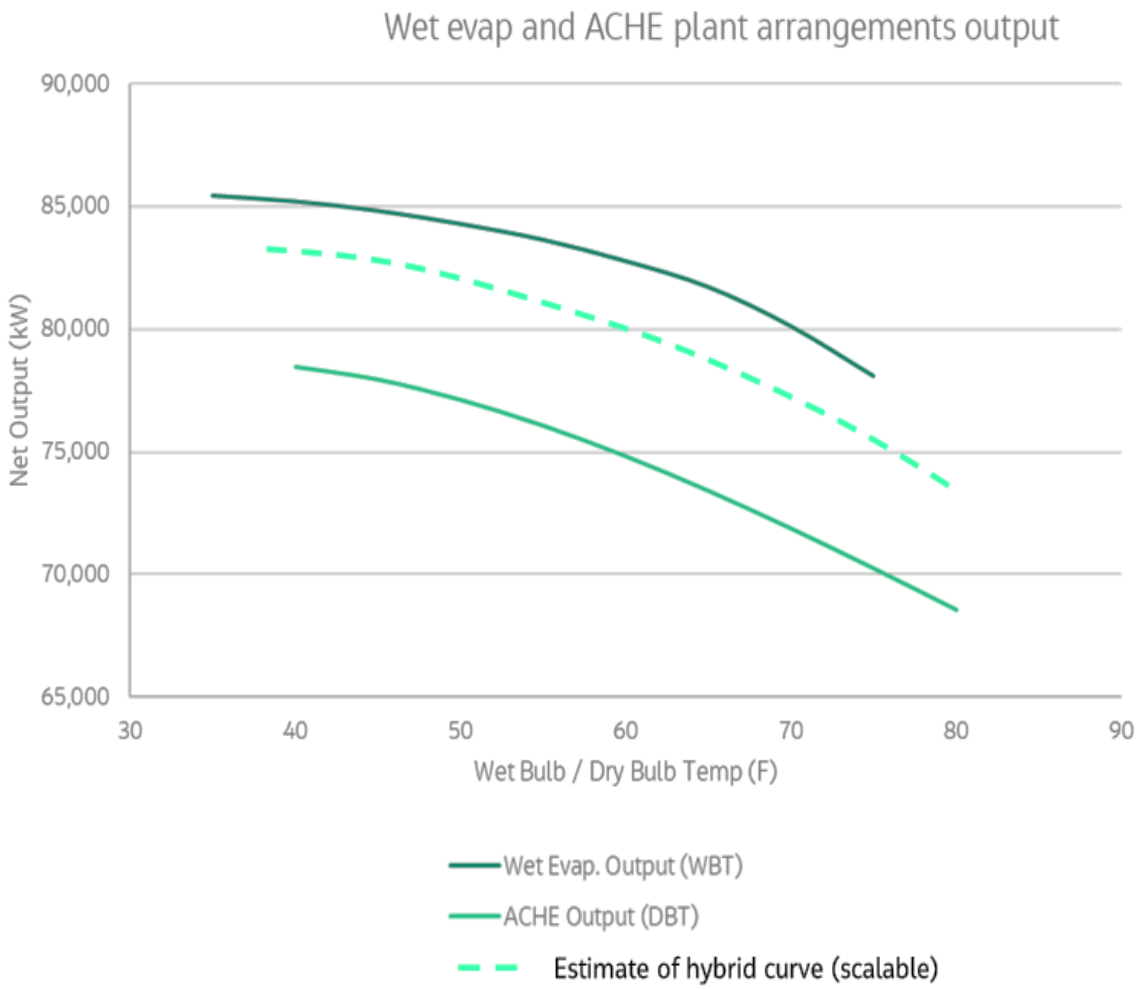
Cases for upgraded rotor & plant facilities



Cooling Tower Upgrade Options

Cooling Tower Analysis





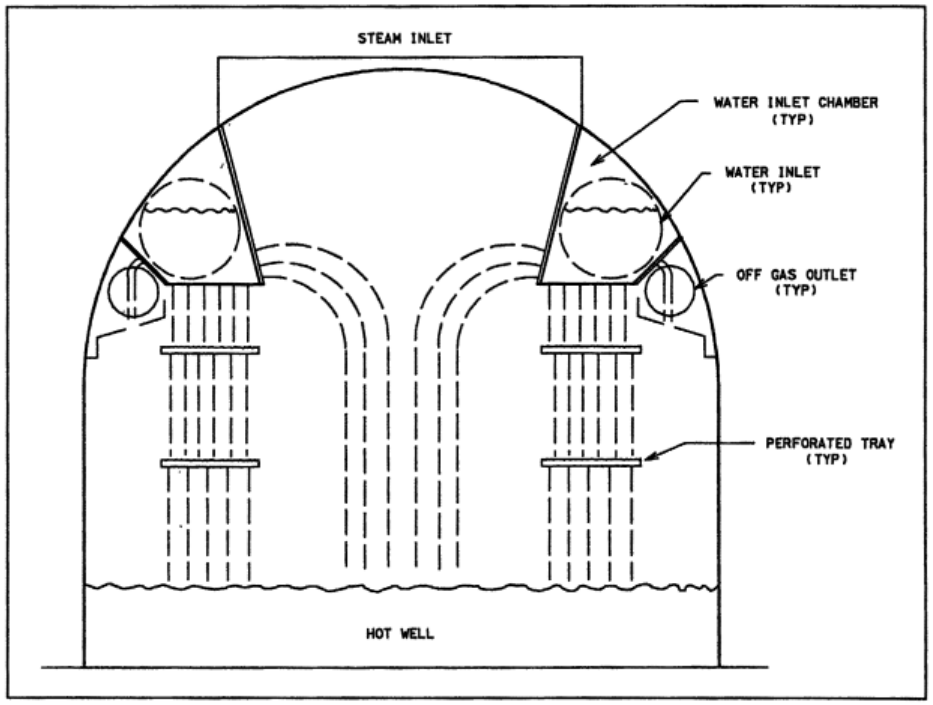
Occam's ~~Razor~~ Cooling Tower

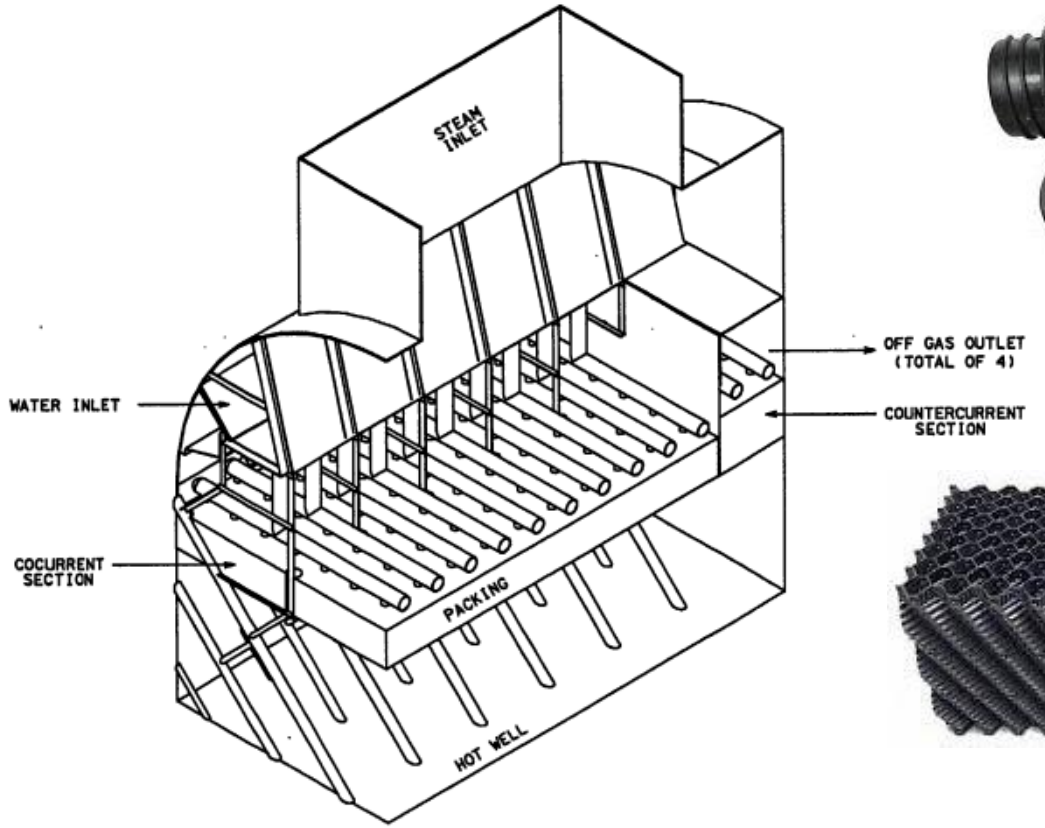
The simplest solution is often the best (i.e., replace-in-kind tower)

Advantages	Disadvantages
• Maintain existing concrete basin & outlet structure, UG water piping, electrical equipment (e.g., XFMRs, switchgear), circulating water pumps • High plant performance • Achievable outage construction schedule • No long-lead components • Lower evaluated cost	• No evaporation reduction • No improvement in performance (e.g., winter dry cooling)

Condenser Study

Goal: Determine new design for NGID steam, if required
Study: Review packing design, gas flooding, water flows
Result: Change packing in gas cooler, change nozzles





Other Projects

Unit 11 Specific

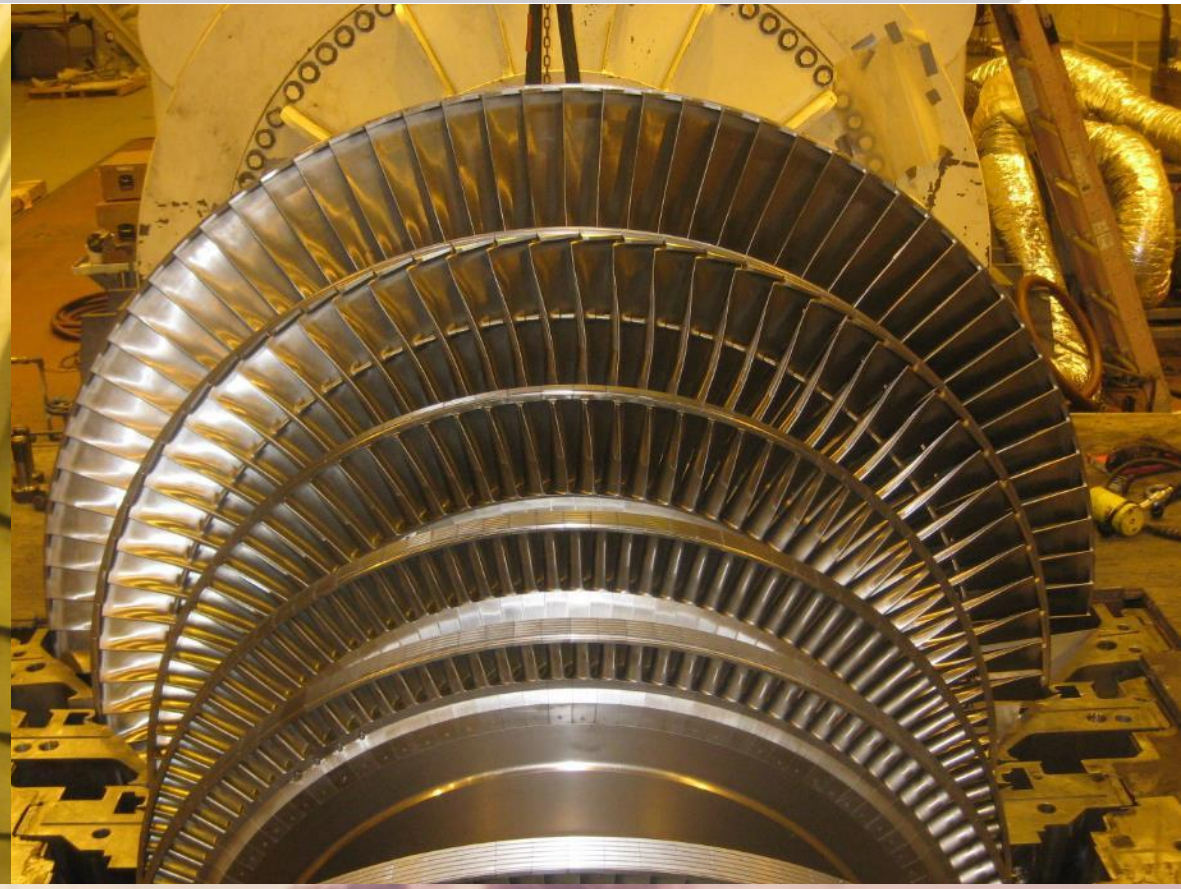
- Control system upgrade
- Twinning Separators
- Upsizing steam header

Steamfield

- Pipeline de-bottlenecking project(s)

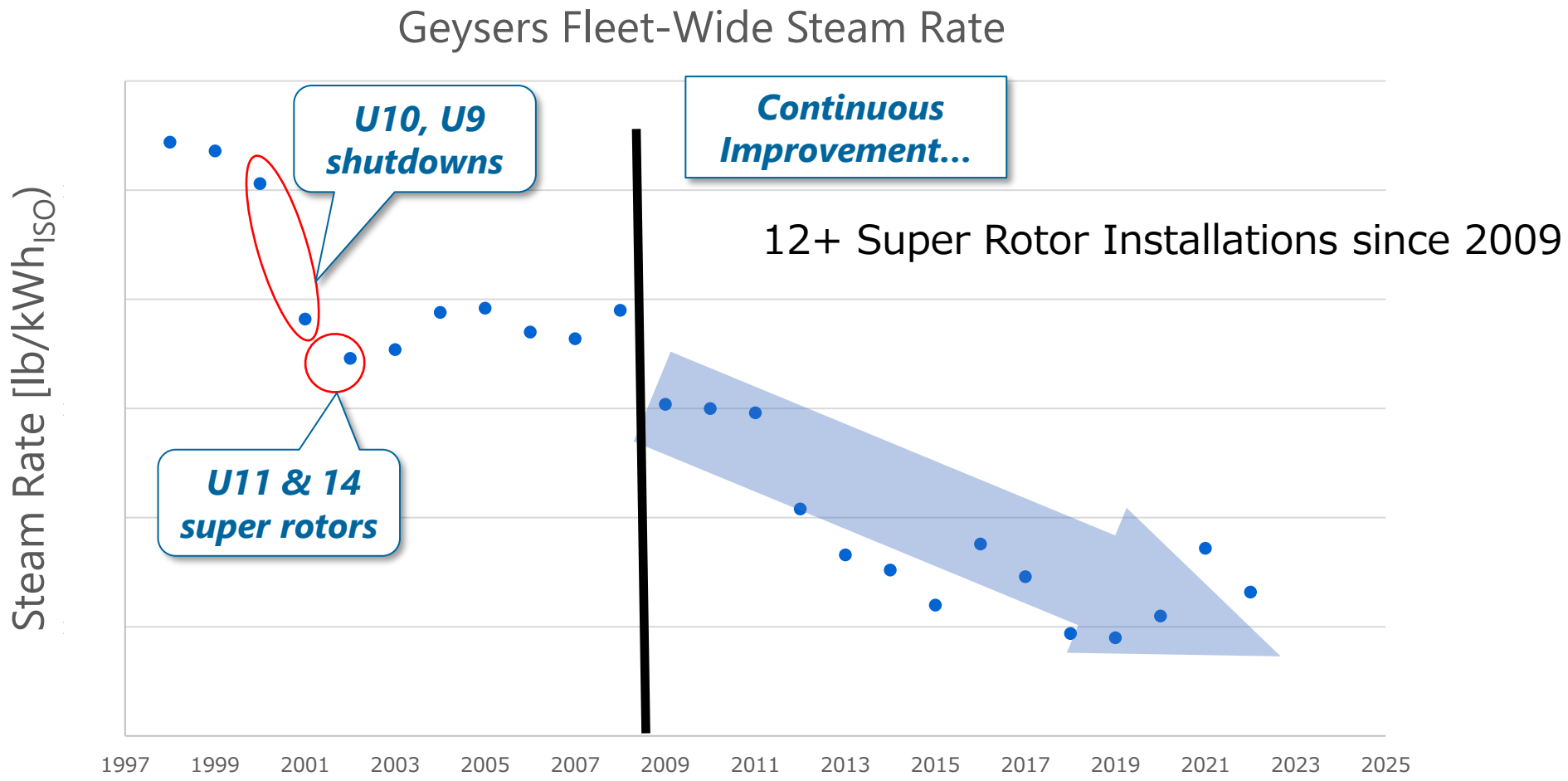
Super Rotor Upgrades!

TOSHIBA



Meeting the Challenge

TOSHIBA



10% Improvement in steam rate since 2000

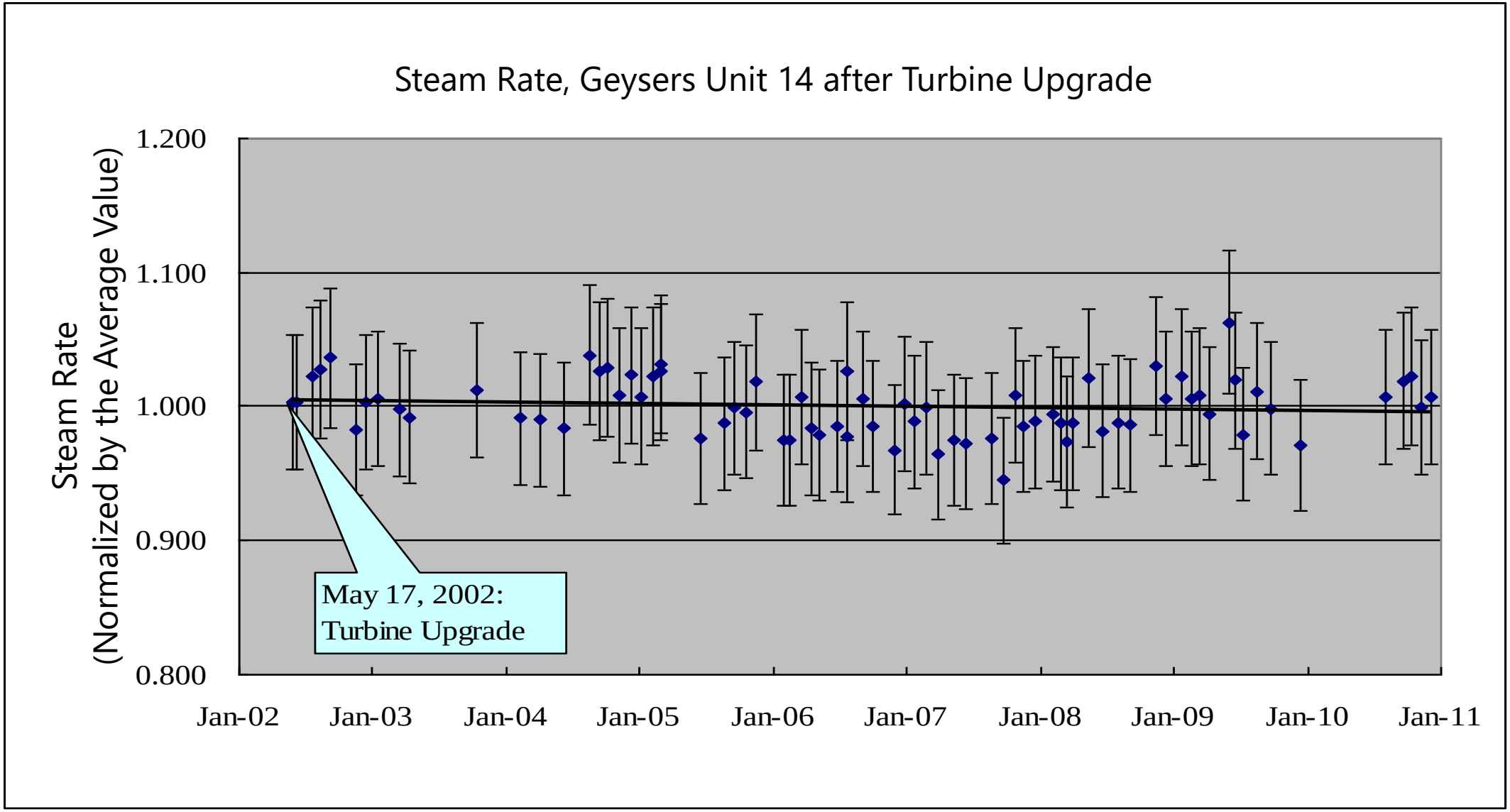
Case Study: U11 Eagle Rock

TOSHIBA

	2002	2024	Units
Turbine Steam Rate	**3% Improvement**	**11% Improvement**	lb/kWh

Continuous Improvement for Geysers reliability and conserving their steam resource.

Case Study: Generation 1.0 Technology



Toshiba & Calpine Partnership

TOSHIBA

- Decades of partnership with mutual interest in advancing geothermal energy
  - Commitment to long-term success
  - Open communication
  - Timely involvement by both parties to address any equipment or service support needed
  - Best-in-class equipment (STG) delivery based on each location's need
  - New innovations developed together to support super rotor program and new maintenance / service and upgrades/retrofits

Geysers “Super Rotor” Upgrades, Installed to Date

TOSHIBA

Unit	Plant	Date
U14	Sulphur Springs	5/16/2002
U11	Eagle Rock	6/20/2002
U5	McCabe5	1/2/2009
U6	McCabe6	2/28/2009
U7	RidgeLine7	6/19/2009
U8	RidgeLine8	6/22/2009
U17	LakeView	5/4/2011
U18	Socrates	5/7/2012
U19-2	Calistoga19-2	6/28/2013
U20	Grant	11/15/2014
U13	Big Geysers	6/26/2017
U12	Cobb Creek	6/26/2018
U19-1	Calistoga19-1	7/17/2021
U16	Quicksilver	6/15/2022
U11	Eagle Rock	Fall 2025!

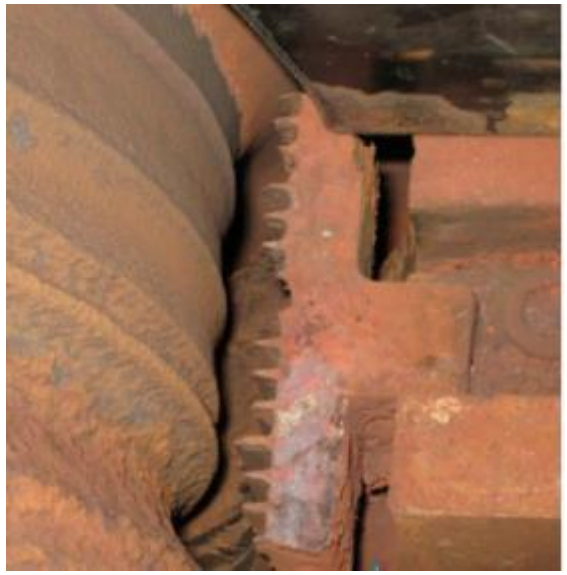
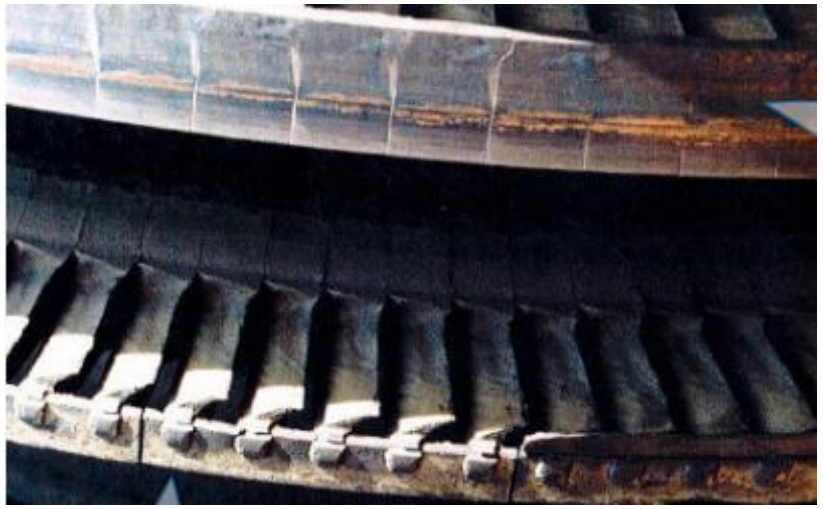
Continuous Improvement of the Steam Path

TOSHIBA

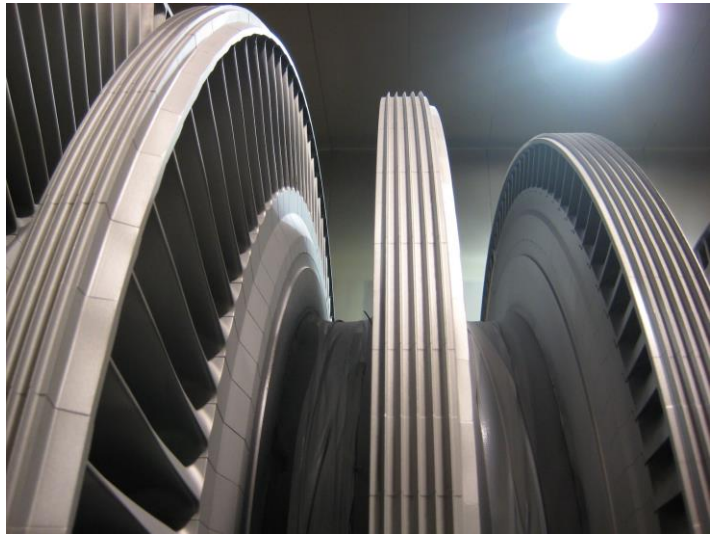
- Evaluations performed as outputs of service outages and Co-operational research with Calpine
  - Primary Research Topics for Continuous Improvement (2002 ~ Present)
    - Geothermal steam conditions vary from site to site. Evaluations of the Steam conditions and service damages.
      - Erosion & fatigue cracking on blades
      - Stress corrosion cracking on wheel surfaces and hook fits
      - Erosion in rotor sealing areas
      - Erosion on casing and diaphragm sealing areas
      - Last stage blade fatigue stress cracking
      - Moisture impingement pitting
      - Scale build-up

Continuous Improvement

TOSHIBA


Typical Major Outage Pre-Super Rotor Program…



Generation 1.0 Super Rotor Technology After 8 Years of Operation

Continuous Improvement

TOSHIBA

Item	Problem in Original Units	1st GEN Super Rotor 2002～	2nd GEN Super Rotor 2013~(additional to 1st GEN)
Rotor shaft	- Erosion of the packing area	- Coating packing area - Upgraded Rotor Material	-
Wheel	- SCC in 2nd and 3rd stages - SCC in wheel filet - Erosion of balance groove	- Increased shaft diameter - Titanium blades - Coating & peening - Improved groove type	-
Blades	- Corrosion in airfoil - Erosion in tenon &shroud - Corrosion fatigue cracking	- Snubber blades - Titanium blades - 23" A++ LSB	- Snubber blade in L-0 - Moisture Extracting Blade in L-1/L-2 - 26" LSB
Nozzle	- Erosion/Corrosion in nozzle partitions - Erosion at tip fins - Erosion in nozzle packing	- Coated nozzle partitions - Flat tip nozzle & finned snubber blades - Stainless steel replaceable packing	- Diaphragm material upgrade in 2nd~4th stages
Casing	- Erosion of the diaphragm sealing area	- Anti-erosion seal plate (stainless steel)	-
Gland packing	- Erosion/Corrosion of the packing casings and rings	- Stainless steel packing casings and rings	-

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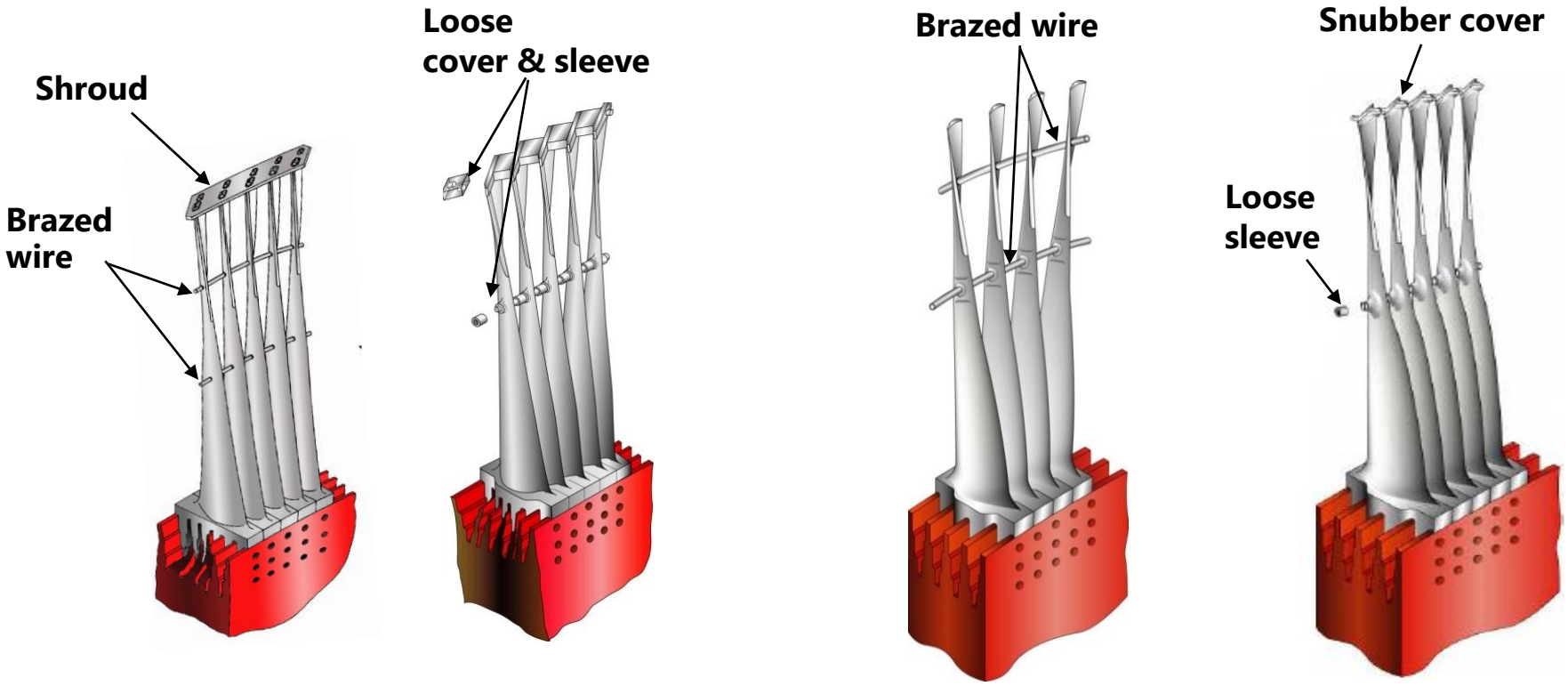
Comparison of 23"/26" Last Stage Blades

✓ ***Structural comparison of each LSB***



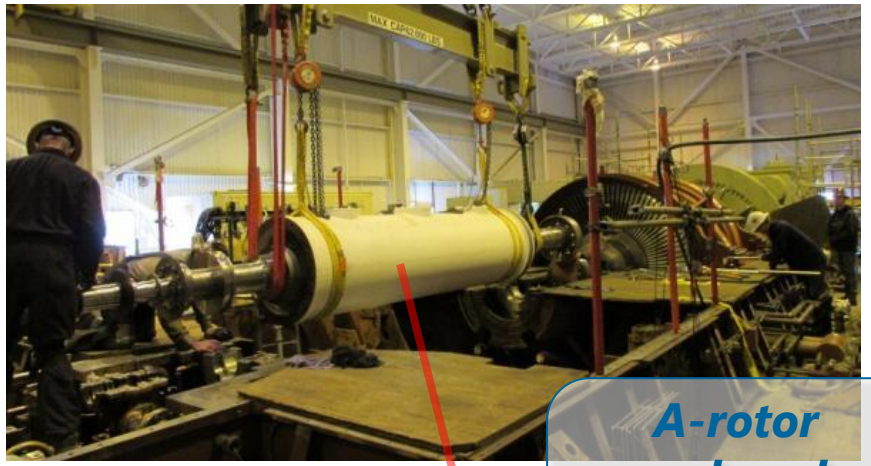
Original 23" **Advanced 23"A++** **Original 26"** **Advanced 26"**

1st GEN **2nd GEN**

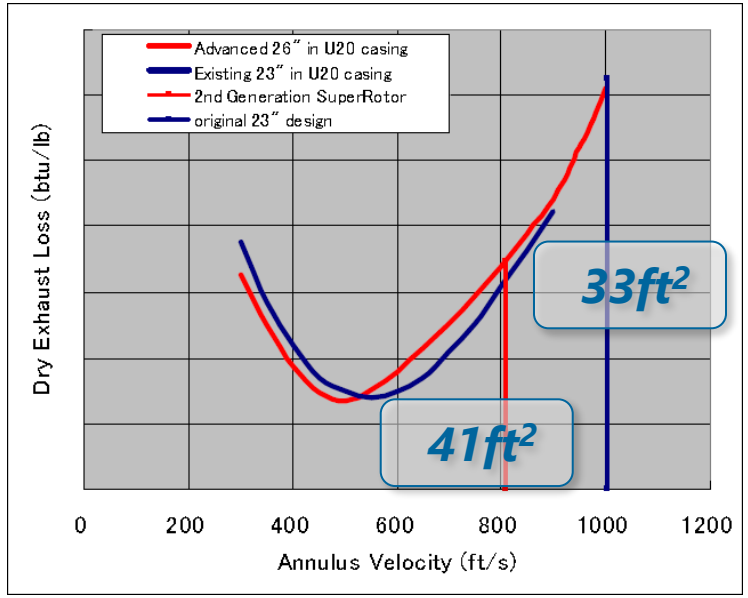
Case Study: Grant 2.0 Super Rotor Technology

TOSHIBA

- Conversion
  - 4-flow→2-flow
  - 23″→26″ LSB

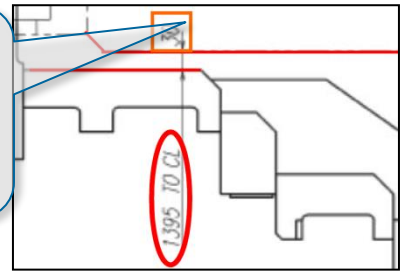


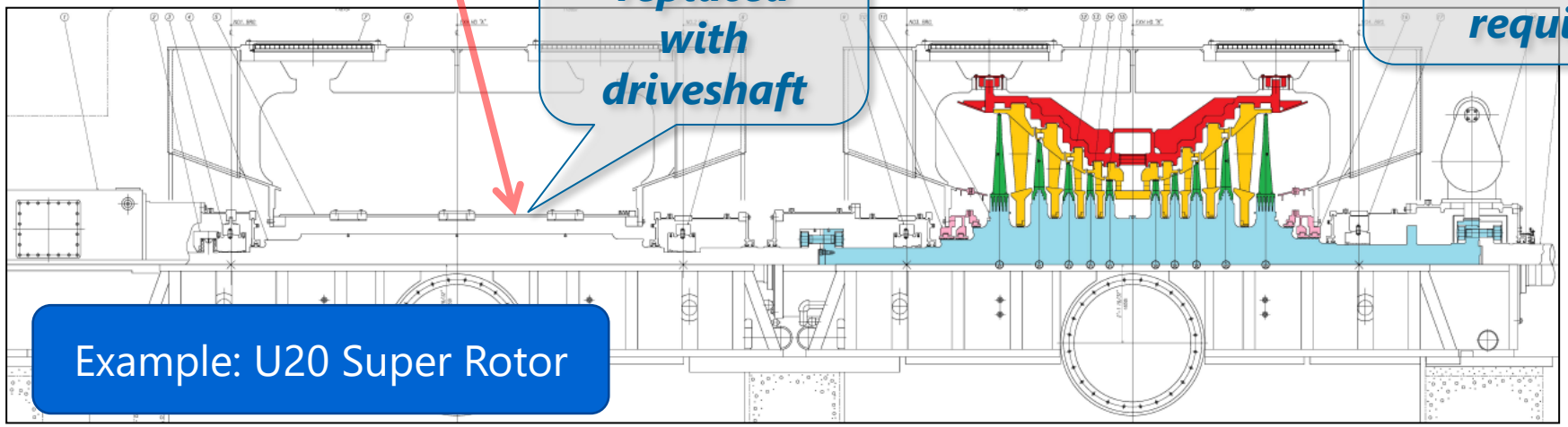
L-0 annular area↑25%.



A-rotor replaced with driveshaft

And, no outer case mods required.





Example: U20 Super Rotor

Case Study: RETROFIT Super Rotor Technology

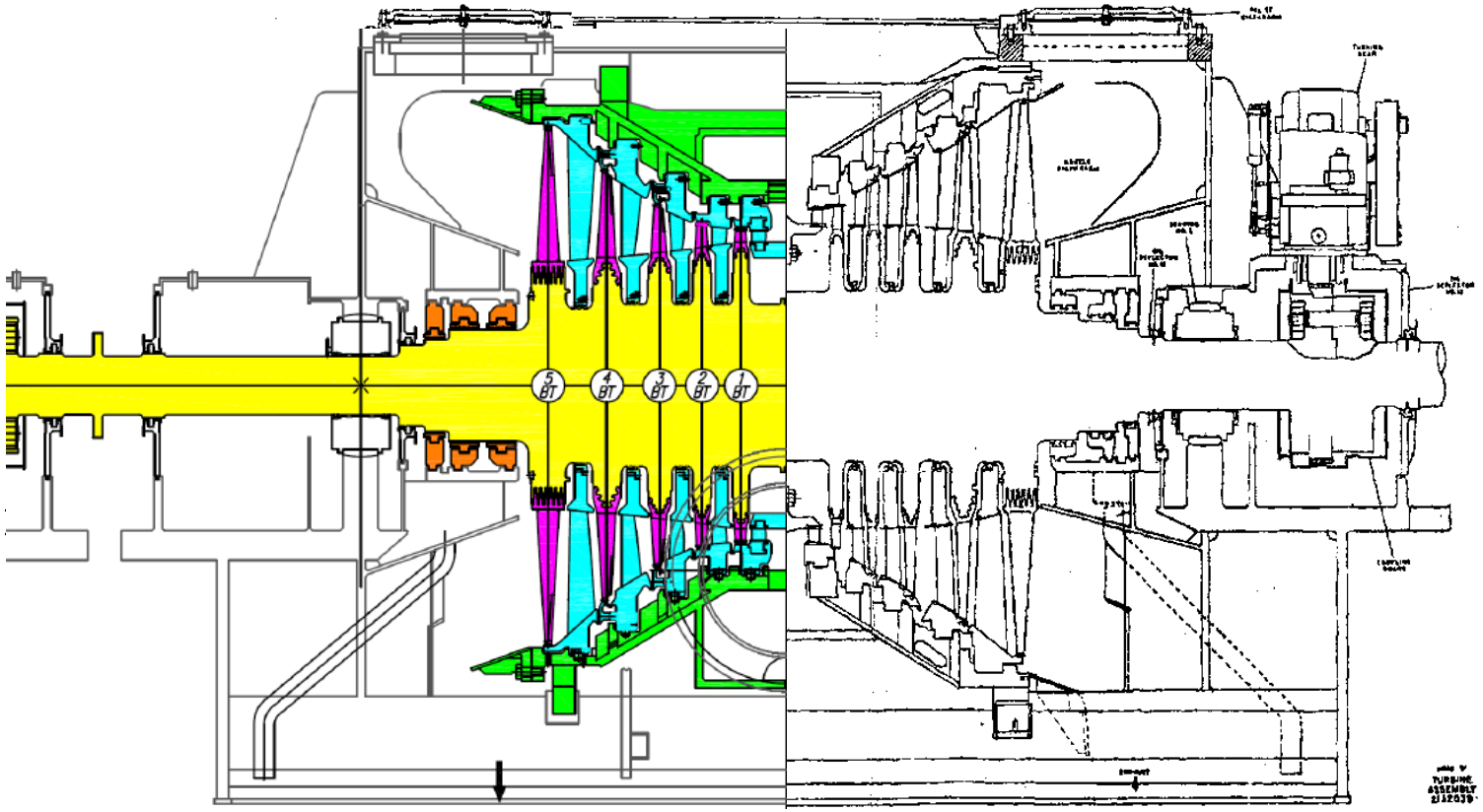
TOSHIBA

GEN2.5 – Another Evolution started with U13 and applied to U12, U19-1 and U16.

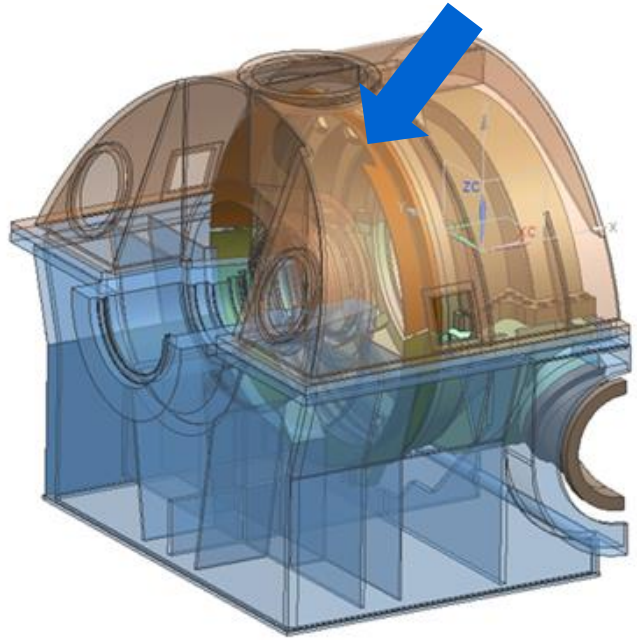
- Reaction type blading with increase stage counts
- Robust, wider chord nozzle/blade with wheel & diaphragm construction
- Unique to U13 was the Retrofit of a OOEM Unit

Post Super Rotor Upgrade

Existing Unit



Upper half rib is cut off significantly reducing exhaust losses



Geysers Super Rotor Upgrades

Units 5-8, 11, 12, 13, 14, 16, 17, 18, (19-1,19-2), 20

TOSHIBA

Optimization for Decreased Steam Deliverability Reliability and Efficiency Improvements

Applied reliability improvement technologies

- Special coating technologies for turbine components
- Optimized design and material selection to prevent SCC
- Optimized stress controlled design
- Optimized design for outages works at geothermal units
- Design to extract drainage from steam path to improve turbine efficiency

Realized Performance Optimization and 14+ Years to Date of Operation Without Opening Casing

Super Rotor Technologies Applied Worldwide

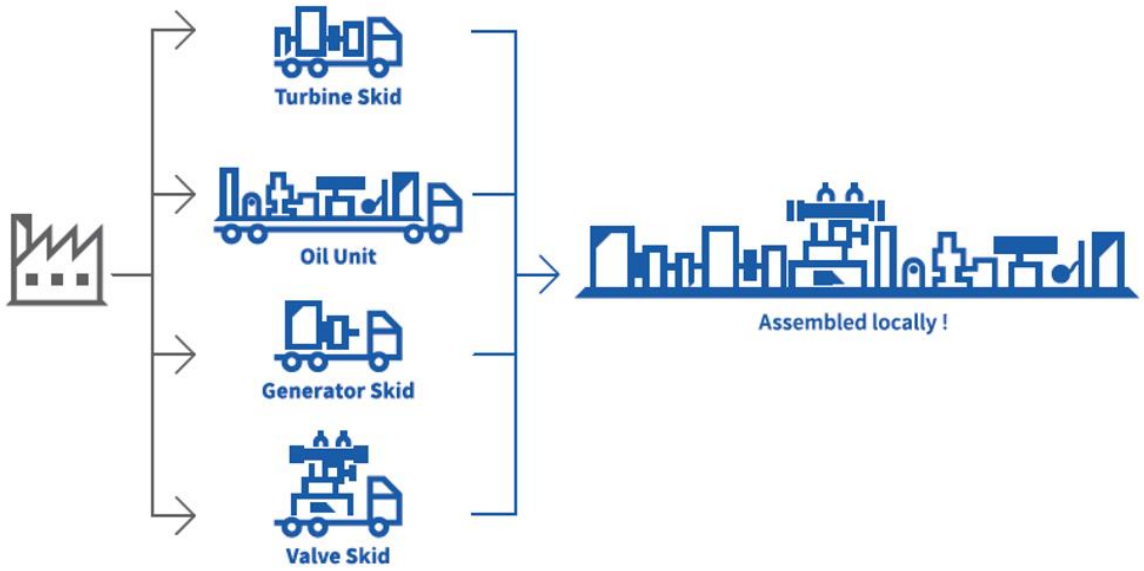
TOSHIBA

International Geothermal Power Plants (Non-Geysers)							
Super Rotor Technologies	**Plant P**	**Plant L**	**Plant H**	**Plant T**	**Plant S**	**Plant O**	**Plant B**
Rotor upgrade material	✓	✓	✓	✓	✓	✓	✓
Rotor Coating			✓		✓		
Snubber Blade	✓	✓	✓	✓	✓	✓	✓
Moisture Extracting Blade		✓	✓	✓	✓	✓	
23″A++LSB	✓						✓
26″A LSB (31.2″)			✓	✓		✓	
Coated Nozzle Partition			✓				
Stainless replaceable packing			✓				
Anti erosion seal plate		✓	✓	✓	✓		
Stainless packing casing			✓	✓			

New Equipment Innovations

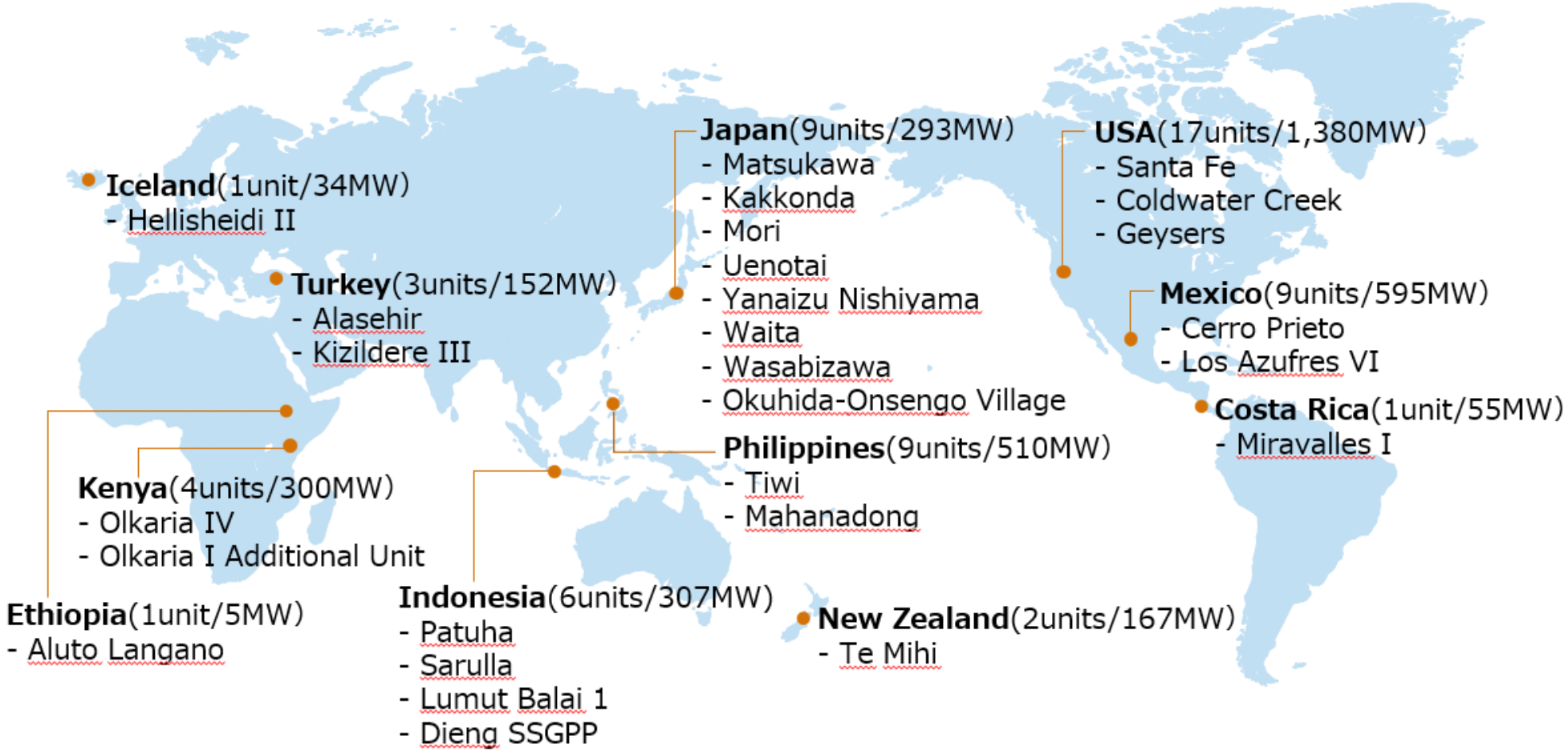
- Depleted gas and oil wells contain residual heat which require new approaches to harnessing the steam from underneath
- There are smaller areas of geothermal activity that can be addressed with equipment that is able to support lower megawatt opportunities
- Companies such as Toshiba and others have equipment solutions that can target these areas effectively with a small footprint and efficient design

Geoportable™ equipment can be installed in a shorter period, and, in many cases, using existing wells resulting in quicker power availability.



Geothermal Steam Turbines Supplied Worldwide

TOSHIBA



As of March 2024

Total: 62 Units / 3,798MW

- First Shipment 1966 -

Looking Forward to More Upgrade Projects!

Calpine's Geothermal Visitor Center & Tours

The Geysers have become an important energy source for the community as well as a historic landmark to be proud of.

TOURS! Calpine offers tours from various Sonoma County locations and from the Visitor Center in Middletown. For a full schedule visit www.geysers.com.

Learn More About The Geysers – www.geysers.com

- Great source of information
  - Geothermal Energy
  - Historic Timeline
  - Recharging The Geysers
  - Community Commitment
  - Enhanced Geothermal Systems
  - The Visitor Center and Tours

THE GEYSERS CALPINE
www.geysers.com

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Thank You!

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