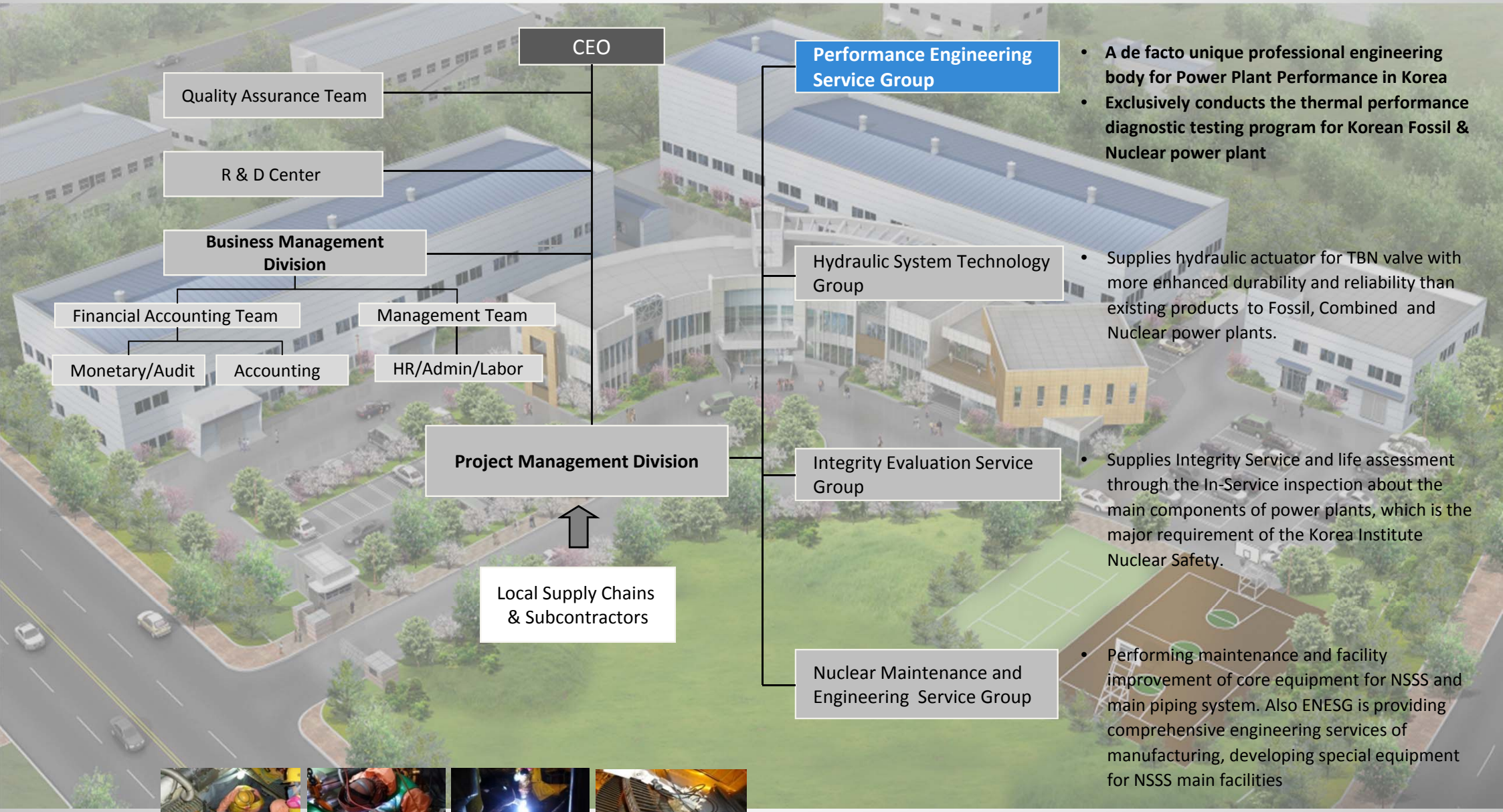
Engineering Service for
Power Plant Performance Improvement Program

enesG worldwide –Performance Engineering Service Group

Introduction to enesG worldwide Performance Engineering Service Group

Organization and Business

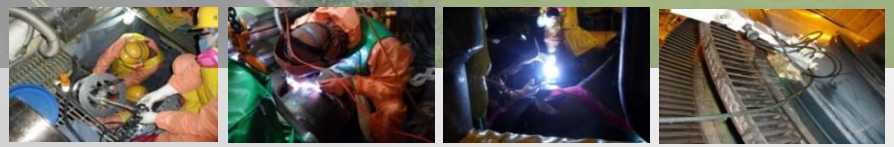


- **A de facto unique professional engineering body for Power Plant Performance in Korea**
- **Exclusively conducts the thermal performance diagnostic testing program for Korean Fossil & Nuclear power plant**

- Supplies hydraulic actuator for TBN valve with more enhanced durability and reliability than existing products to Fossil, Combined and Nuclear power plants.

- Supplies Integrity Service and life assessment through the In-Service inspection about the main components of power plants, which is the major requirement of the Korea Institute Nuclear Safety.

- Performing maintenance and facility improvement of core equipment for NSSS and main piping system. Also ENESG is providing comprehensive engineering services of manufacturing, developing special equipment for NSSS main facilities

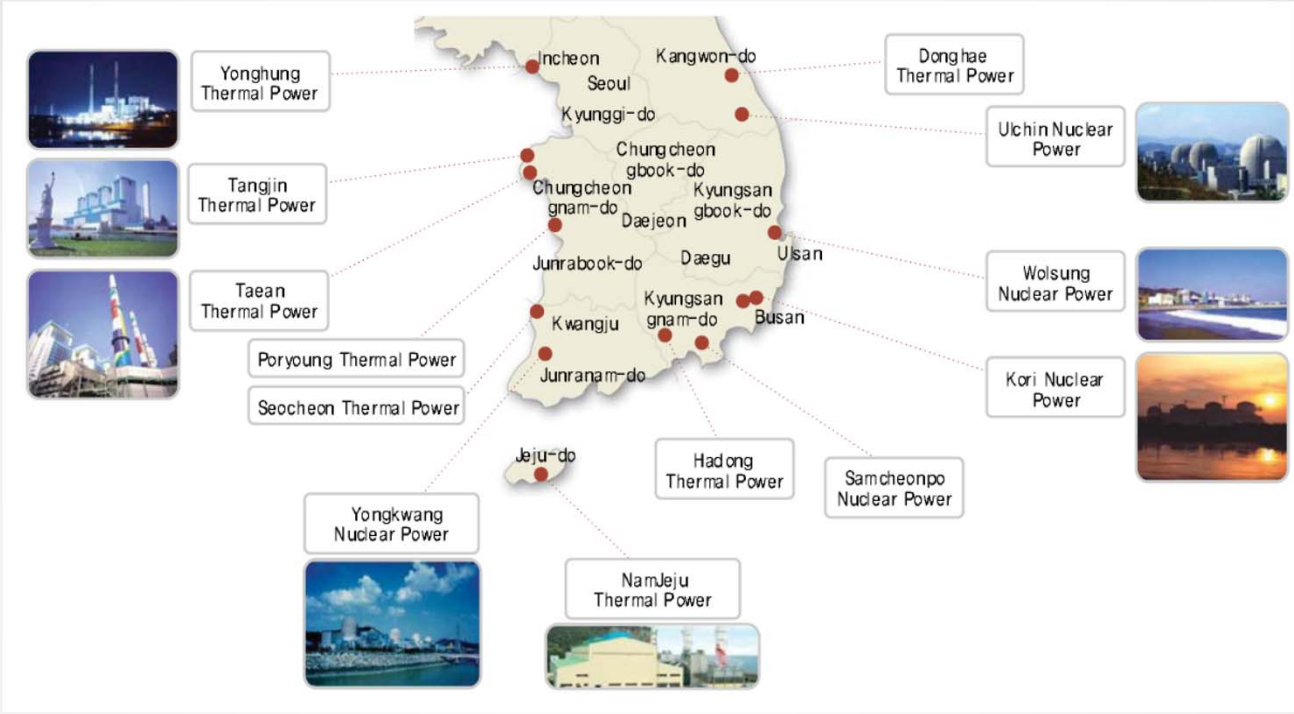


Business Area of Performance Engineering Service Group

enesG worldwide's Performance Engineering Service Group provides total solutions relating to thermal performance of the power plant in the following area;

- Technical proposal and contract review and support for performance guarantee
- Performance acceptance/diagnostic testing service
  - Overall plant or thermal island
  - Individual equipments
  - Third party performance acceptance testing support
- Plant performance improvement program development
- Steam Path Audit (SPA)
- Customized on-line performance monitoring system
- Performance test instrumentation design and supply
- Flow meter calibration

Recent 5 years experience – Domestic



Performance Acceptance Testing Program

- Taean #7,8 Steam Turbine (PTC 6.0)
- Tangjin #7,8 Steam Turbine (PTC 6.0)
- Poryoung #7,8 Steam Turbine (PTC 6.0)
- Hadong #7,8 Steam Turbine (PTC 6.0)

- Yonghung #3, 4 BOP (PTC 12.1 and 12.2)
- Taean #8 BOP (PTC 12.1 and 12.2)
- Tangjin #7, 8 BOP (PTC 12.1 and 12.2)
- Poryoung #8 BOP (PTC 12.1 and 12.2)
- Hadong #7, 8 BOP (PTC 12.1 and 12.2)
- Namjeju #4 BOP (PTC 12.1 and 12.2)
- Namjeju #2 Diesel Power plant (ISO 3046)

Performance Diagnostic Testing Program

- Kori #1,2,3,4 Turbine Cycle (Nuclear)
- Yongkwang #1,2,3,4,5,6 Turbine Cycle (Nuclear)
- Ulchin #2 Turbine Cycle (Nuclear)
- Ulchin #3,4,5,6 Turbine Cycle (Nuclear)
- Wolsung #1, 2,3,4 Turbine Cycle (Nuclear)
- ShinKori #1,2 Turbine Cycle (Nuclear)
- ShinWolsung #1,2,3,4 Turbine Cycle (Nuclear)
- Hwasung Cogeneration Steam Turbine
- Hadong #1,2,5,6 Boiler and Turbine Cycle (Fossil)

enesG achieved long term agreement with KHNP(Korea Hydro & Nuclear Power) for periodical (6 years) performance diagnostic testing program for operating 22 units.

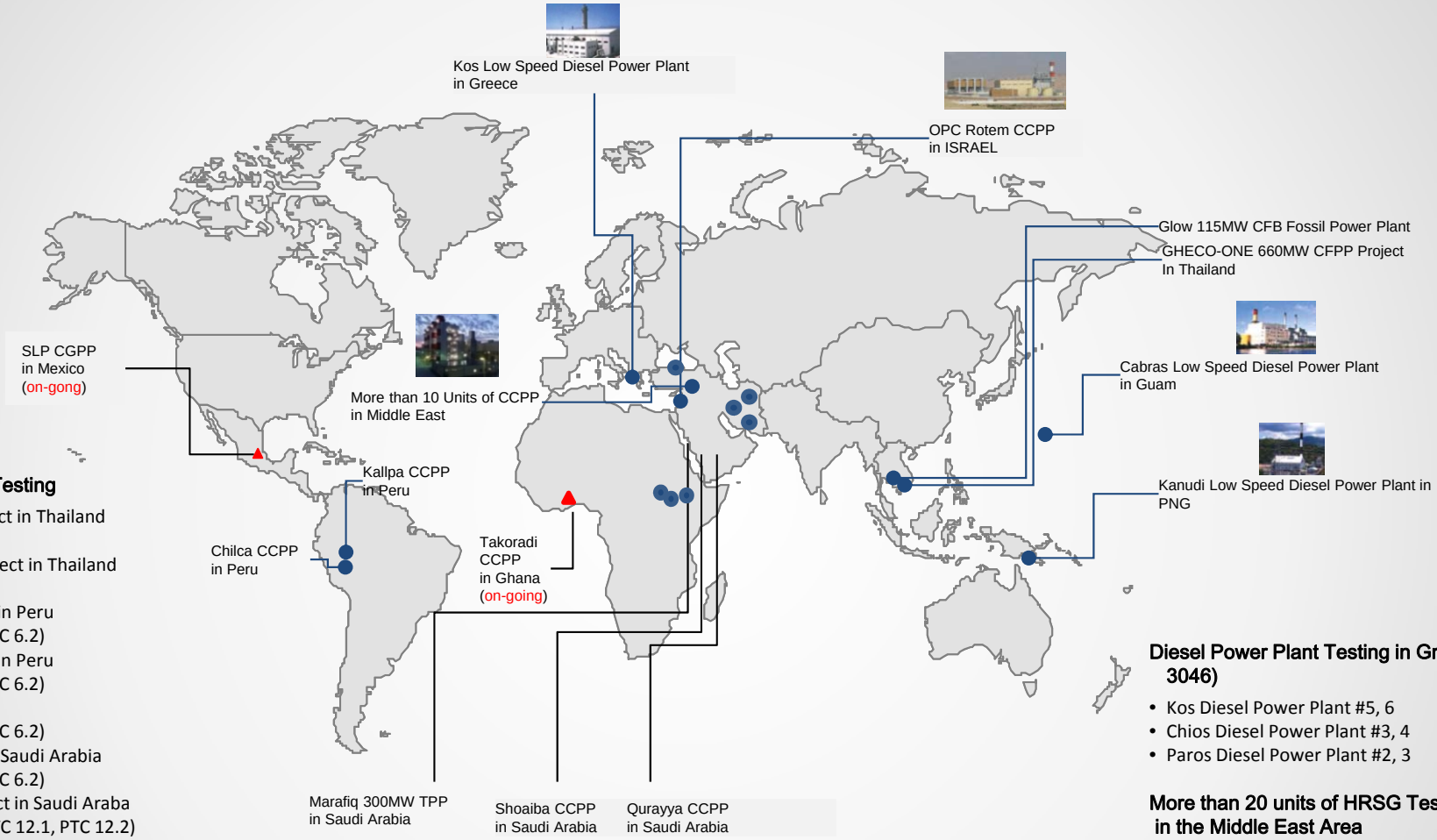
Third Party Performance Acceptance Testing Support

- GS EPS Bukok CCPP Block 2 (PTC 46)
- Poryoung #1,2 Steam Turbine Retrofit (PTC 6.0)
- Poryoung #1,2 Boiler Retrofit (PTC 4.0)
- Busan Junggwan Cogeneration (PTC 46)
- Song-Do Cogeneration (PTC 46)
- Gwangju Suwan Cogeneration (PTC 46)
- Busan Junggwan Cogeneration (PTC 46)
- Hundai Green Power Gas Thermal Power Plant (PTC46, PTC4.0, PTC6.0)

On-line Performance Monitoring System

- GS EPS Bukok CCPP Unit 1 and 2
- KHNP's operating 22 Units (Completed in 2012)

Recent 5 years experience – Overseas



Performance Acceptance Testing

- Glow CFB 115MW FPP Project in Thailand (PTC 46, PTC 4.0, PTC 6.0)
- Gheco PCB 660MW FPP Project in Thailand (PTC 46, PTC 4.0, PTC 6.0)
- Kallpa CCPP Add-on Project in Peru (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Chilka CCPP Add-on Project in Peru (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Rotem CCPP Project in Israel (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Qurayya IPP CCPP Project in Saudi Arabia (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Maragiq 300MW TPP Project in Saudi Araba (PTC 46, PTC 4.0, PTC 6.0, PTC 12.1, PTC 12.2)
- Shoaiba II CCPP Project in Saudi Arabia (on-going) (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Tacoradi II CCPP Add-on in Ghana (on-going) (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Ciproel CCPP Add-on in Cote D'Ivoire (on-going) (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- SLP II CCPP Add-on in Chile (on-going) (PTC 46, PTC 22, PTC 4.4, PTC 6.2)
- Tufanbeyli CFB 150MW FPP Project in Thailand (on-going) (PTC 46, PTC 4.0, PTC 6.0)

Performance Test Instruments Supply

- Full set of HRSG testing instrument (MAPNA)
- Full set of HRSG testing instrument (Benghazi)

Diesel Power Plant Testing in Greece (ISO 3046)

- Kos Diesel Power Plant #5, 6
- Chios Diesel Power Plant #3, 4
- Paros Diesel Power Plant #2, 3

More than 20 units of HRSG Testing (PTC 4.4) in the Middle East Area

Performance Diagnostic Testing

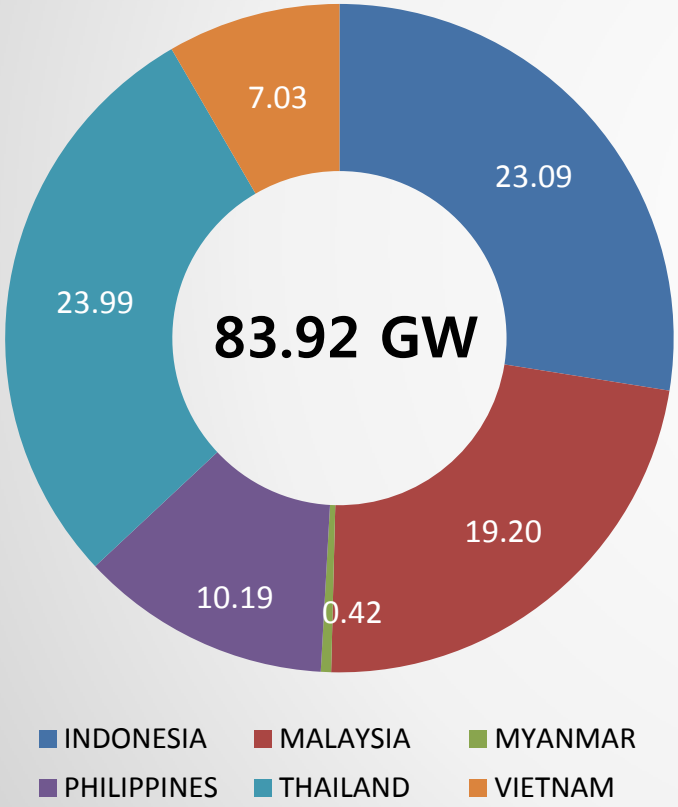
- Cabras Diesel Power Plant #3,4 in Guam
- Kanudi Diesel Power Plant #1,2 in PNG

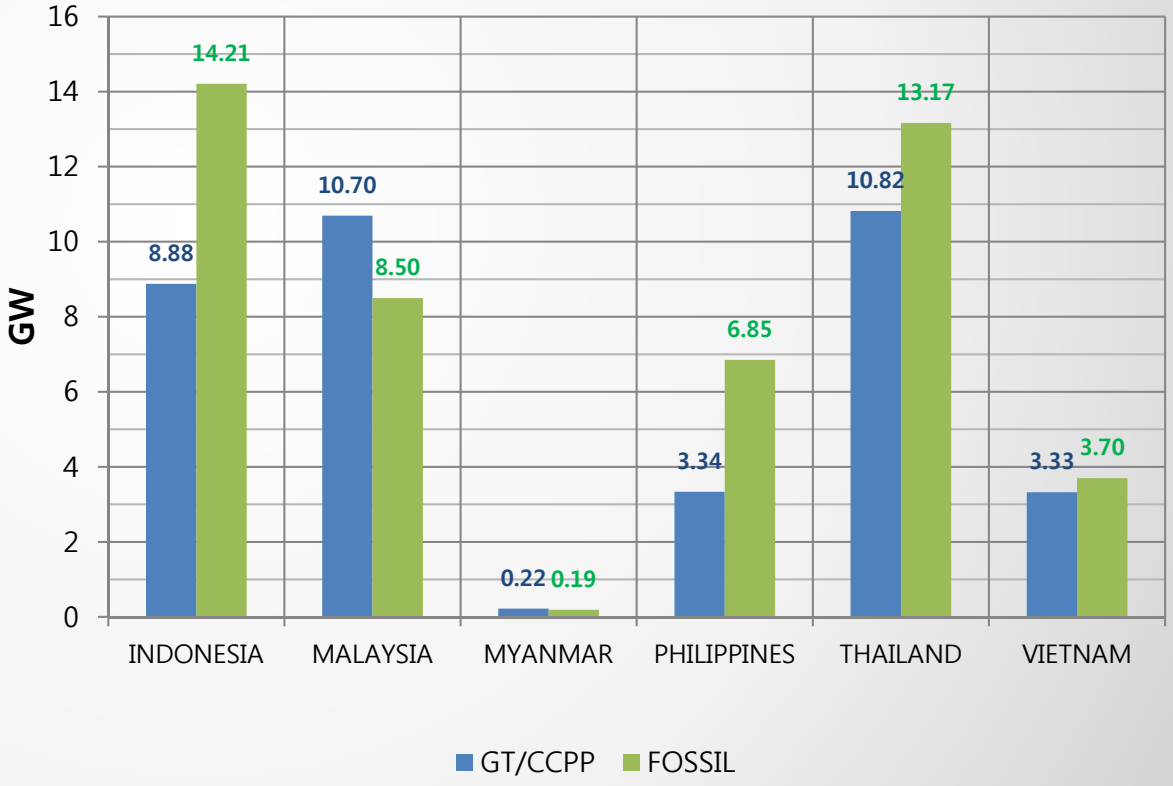
ENESG has been conducting periodical performance diagnostic testing program for the Cabras and Kanudi Diesel Power Plants for last 5 year in annual basis.

Process and Engineering Activities for Plant Performance Improvement Program

Population of the Power Plants over 15 years Operation

83.92 gigawatts located in south-east Asian 6 countries have been operated more than 10 years and need performance improvement programs, such as recapture of performance losses in short term plan and facility retrofit in mid/long term plan.





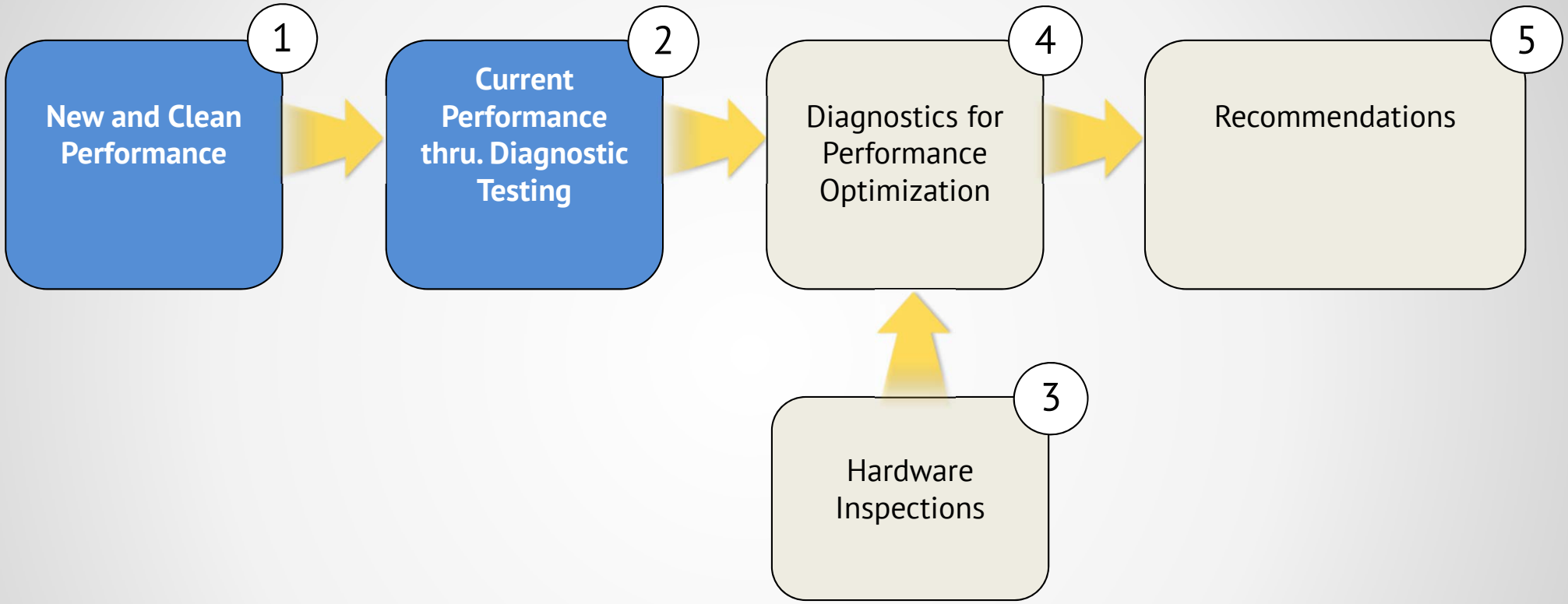
Source : UDI Annual Report

Plant Performance Improvement Program

Engineering Activities that enesG worldwide provides for Plant Performance Improvement Program

	Activities	Purpose
Process 1 **Find AS-IS**	① **Field performance diagnostic testing service**	• Determine performance degradation from new & clean condition • Achieve Inputs for AS-IS Plant Performance Modeling
	② **Energy losses recapture program**	• Recapture energy losses caused by valve or steam trap malfunction, non-ideal operation method and etc.
	③ **AS-IS basis plant performance model**	• Ranking of components based on their contribution to plant performance degradation (sensitivity analysis)
Process 2 **Expect TO-BE**	④ **Feasibility study for Retrofit**	• Conduct thermo-economic analysis to select items to be repaired, improved or replaced from simulation of AS-IS basis plant performance model (needs input from equipment manufactures) • Confirm TO-BE basis plant performance model
Process 3 Retrofit	• Contract and execution of Retrofit	
Process 4 **Verify TO-BE**	⑤ **Field performance acceptance testing service**	• Verify performance improvement and compare with contractual performance guarantee

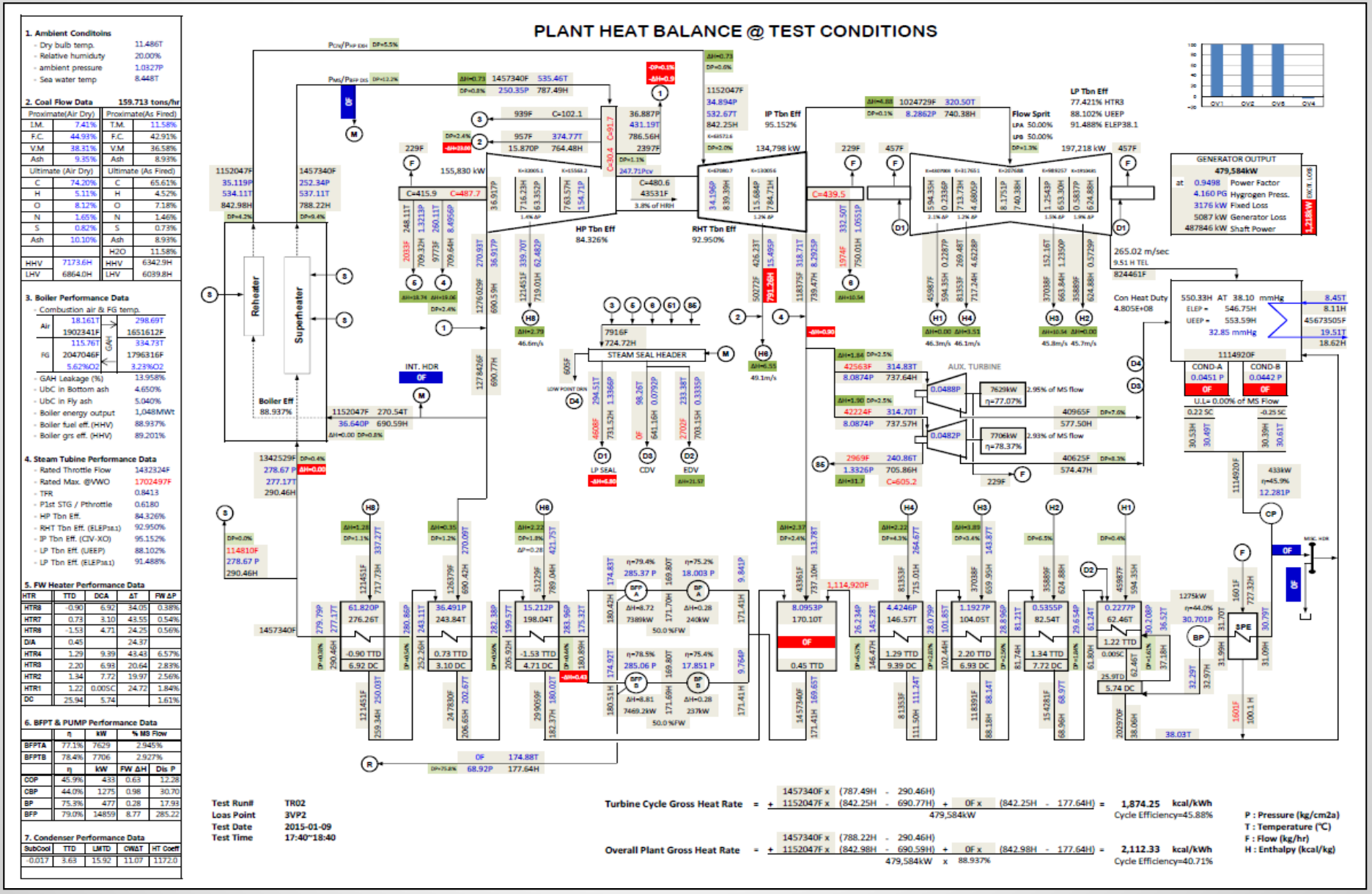
① Find AS-IS : Field Performance Diagnostic Testing Service



The process begins with the collection of data for the new and clean and current operational plant conditions. These data are used performance optimization and cost benefit analysis.

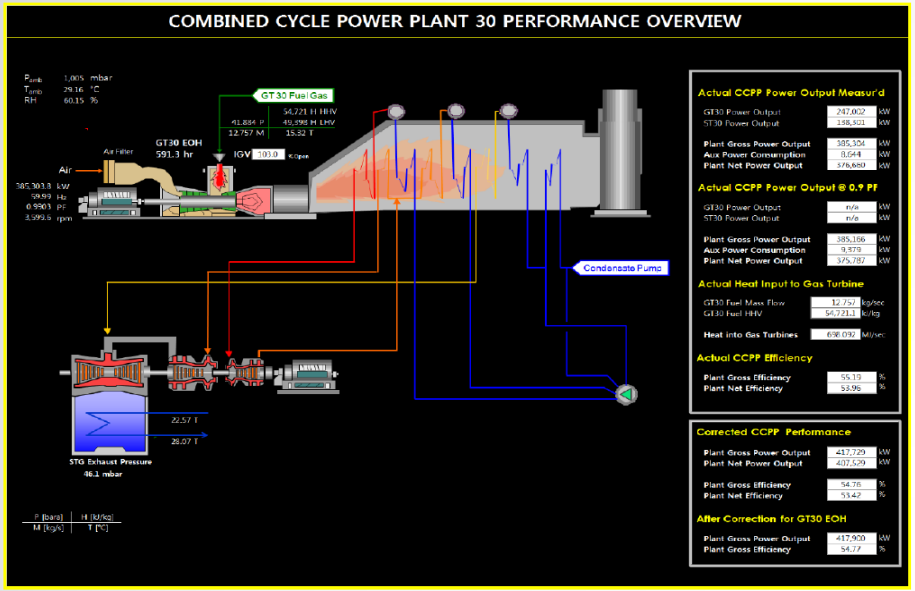
① Find AS-IS : Field Performance Diagnostic Testing Service

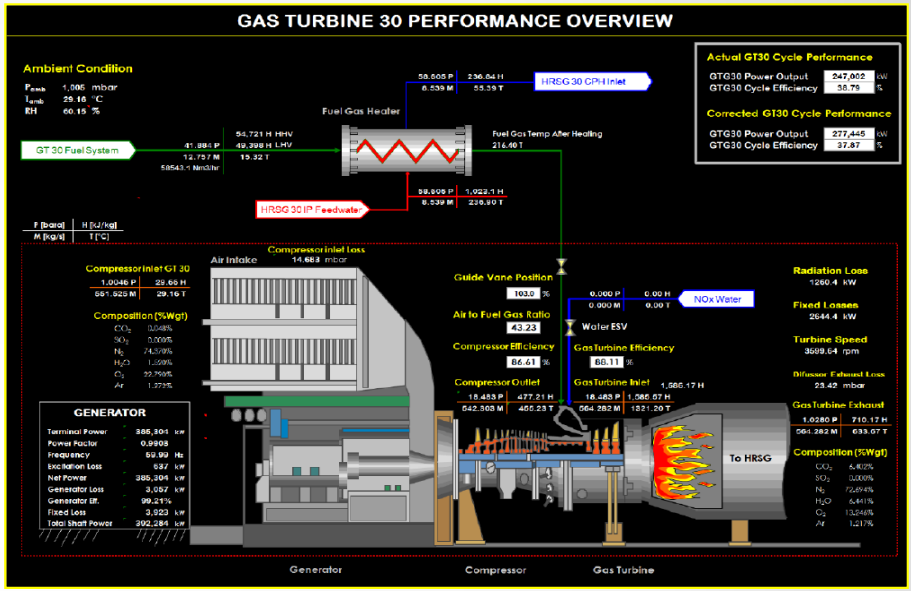
Field Performance Diagnostic Testing Service - Coal Fired Power Plant

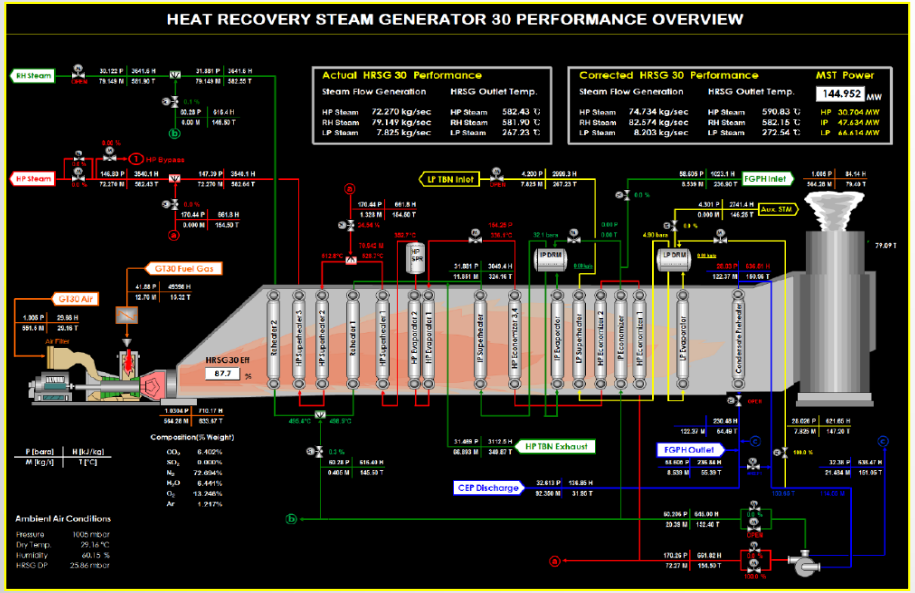


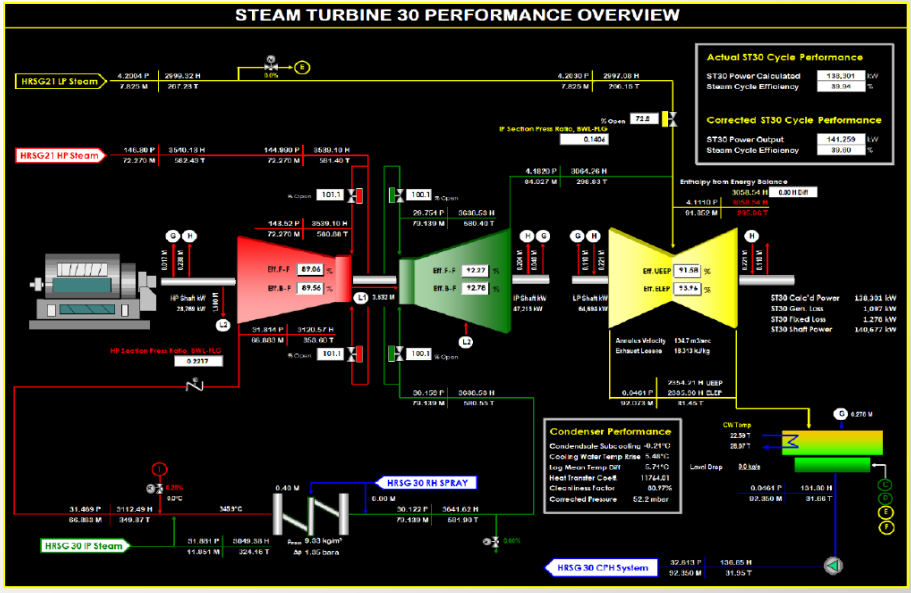
① Find AS-IS : Field Performance Diagnostic Testing Service

Field Performance Diagnostic Testing Service - Combined Cycle Power Plant







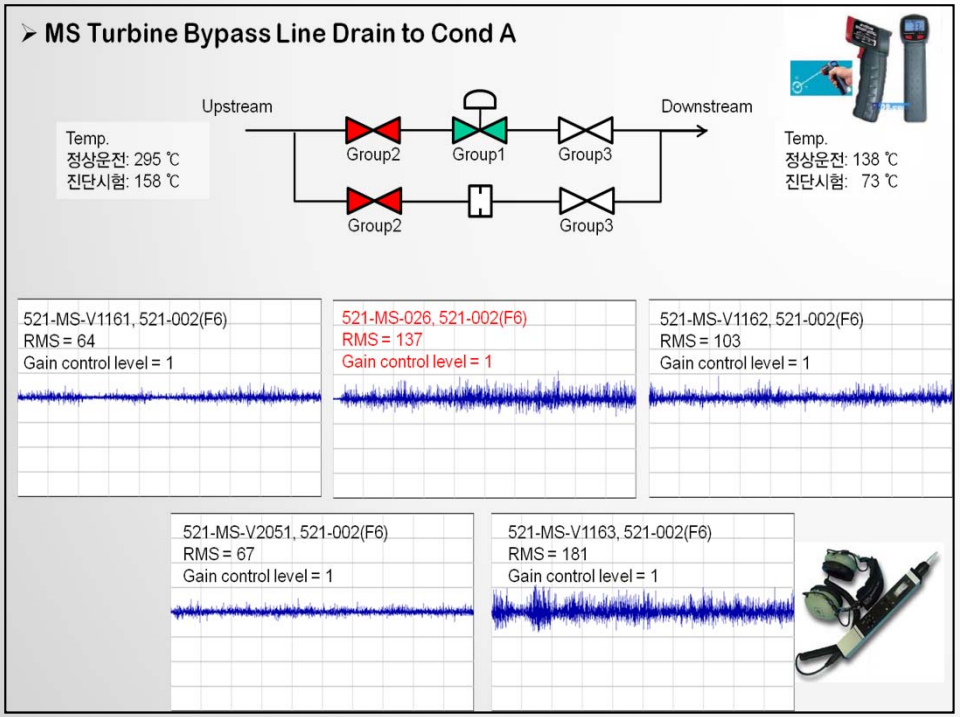


② Find AS-IS : Energy Losses Recapture Program

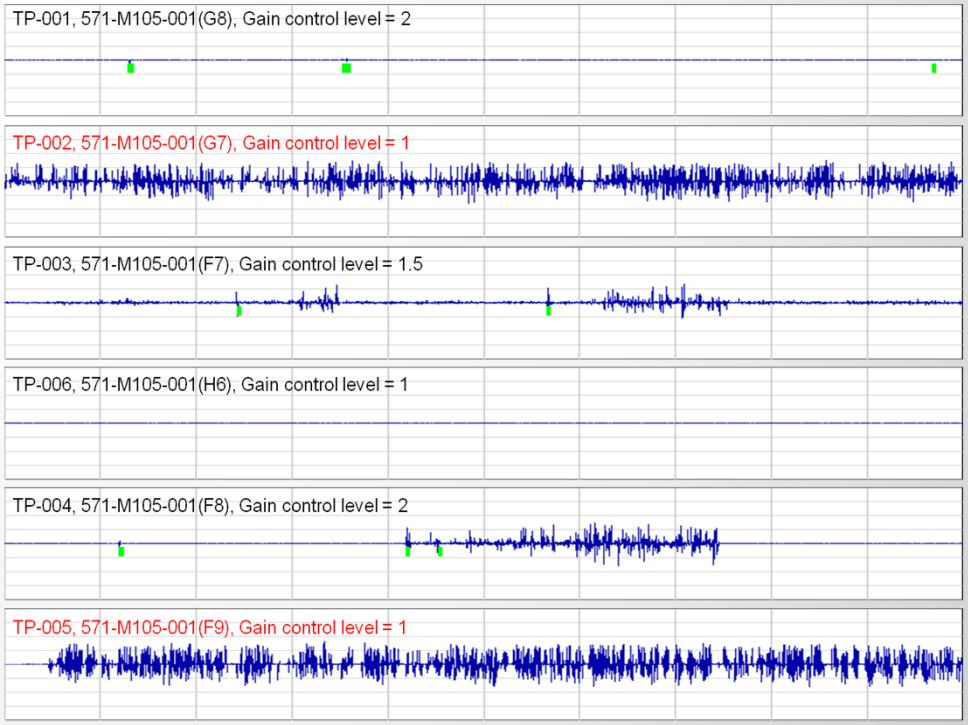
Cycle Isolation Testing

As a part of performance diagnostic testing program, the valves and steam traps which are important to cycle isolation are tested. The result is an effective ranking of each test item based on its impact on a plant's performance.

Valve leakage detection



Steam trap malfunction check



② Find AS-IS : Energy Losses Recapture Program

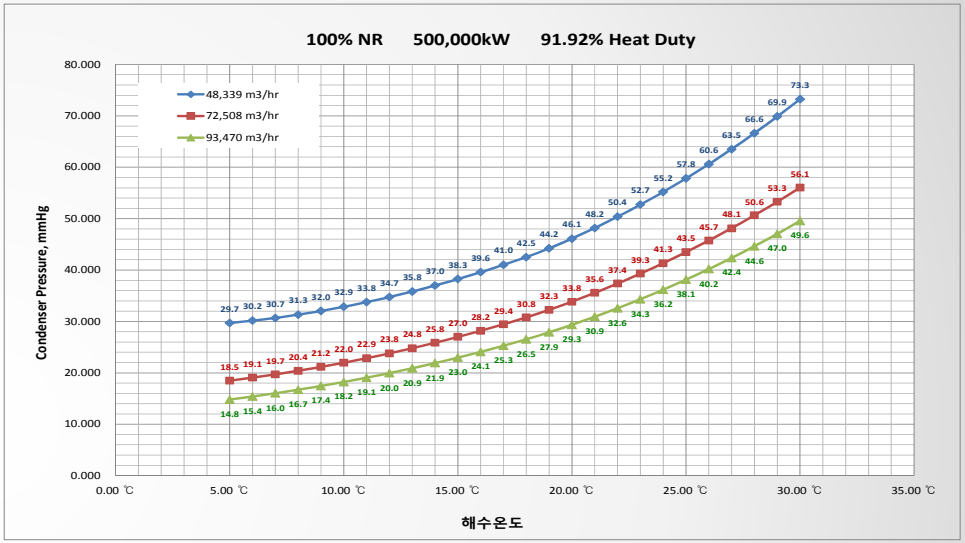
Plant Operation Method for Performance Optimization

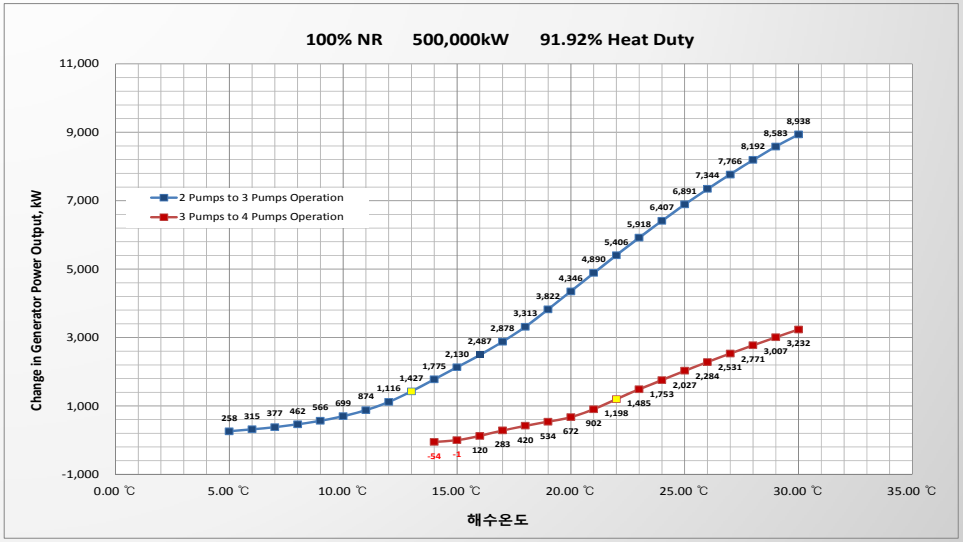
Fossil Power Plant

- Main Steam Temperature
- Main Steam Pressure
- Reheat Steam Temperature
- Condenser Vacuum Pressure
- Superheat Spray Flow
- Reheat Spray Flow
- Boiler Exit Flue Gas - Excess O2

Combined Cycle Power Plant

- Compressor efficiency management
  - Fouling, erosion & foreign object damage monitoring
  - Timing of online washes(minor cleaning)
  - Timing of offline washes(major cleaning)
- Inlet temperature optimization(via spray cooling)





Optimization of the Condenser Vacuum Pressure

② Find AS-IS : Energy Losses Recapture Program

Experience of enesG worldwide in the Nuclear Power Plants

more than 25 MW power losses were recaptured in the field performance diagnostic testing of the 22 nuclear units.

No	Troubles	Actions	Power Loss Recapture	Effective Period
1	Main steam drain line shot-off valve is not fully closed.	Tightly close the valve	1.2 MW	continuous
2	Defective primary flow element (over estimation of reactor thermal power)	Change of flow measurement channel (Average Mode → X Channel Mode)	3.0 MW	continuous
3	Restriction of condenser pressure during winter season	Change the operation procedure	1.0 MW	1 month/year
4	MSR heating steam supply line shutoff valve not fully open (interference)	Machine the valve disc guide during outage	0.9 MW	continuous
5	MSR HP reheater partition plate leak	Change the gasket during outage	0.4 MW	continuous
6	Excessive feedwater heater continuous vent in many units	Optimizes the continuous vent	More than 7.5 MW	continuous
7	Drift of differential pressure transmitters in the primary flow element	Adjust the DP transmitter baes on the precision test instrument	2.5 MW	continuous
8	Defective primary flow element (over estimation of reactor thermal power)	Change of flow measurement channel and change the COLSS constant	2.4 MW	continuous
9	Wrong calculation of nuclear reactor thermal power	Change the thermal power calculation software logic	2.0 MW	continuous

② Find AS-IS : Energy Losses Recapture Program

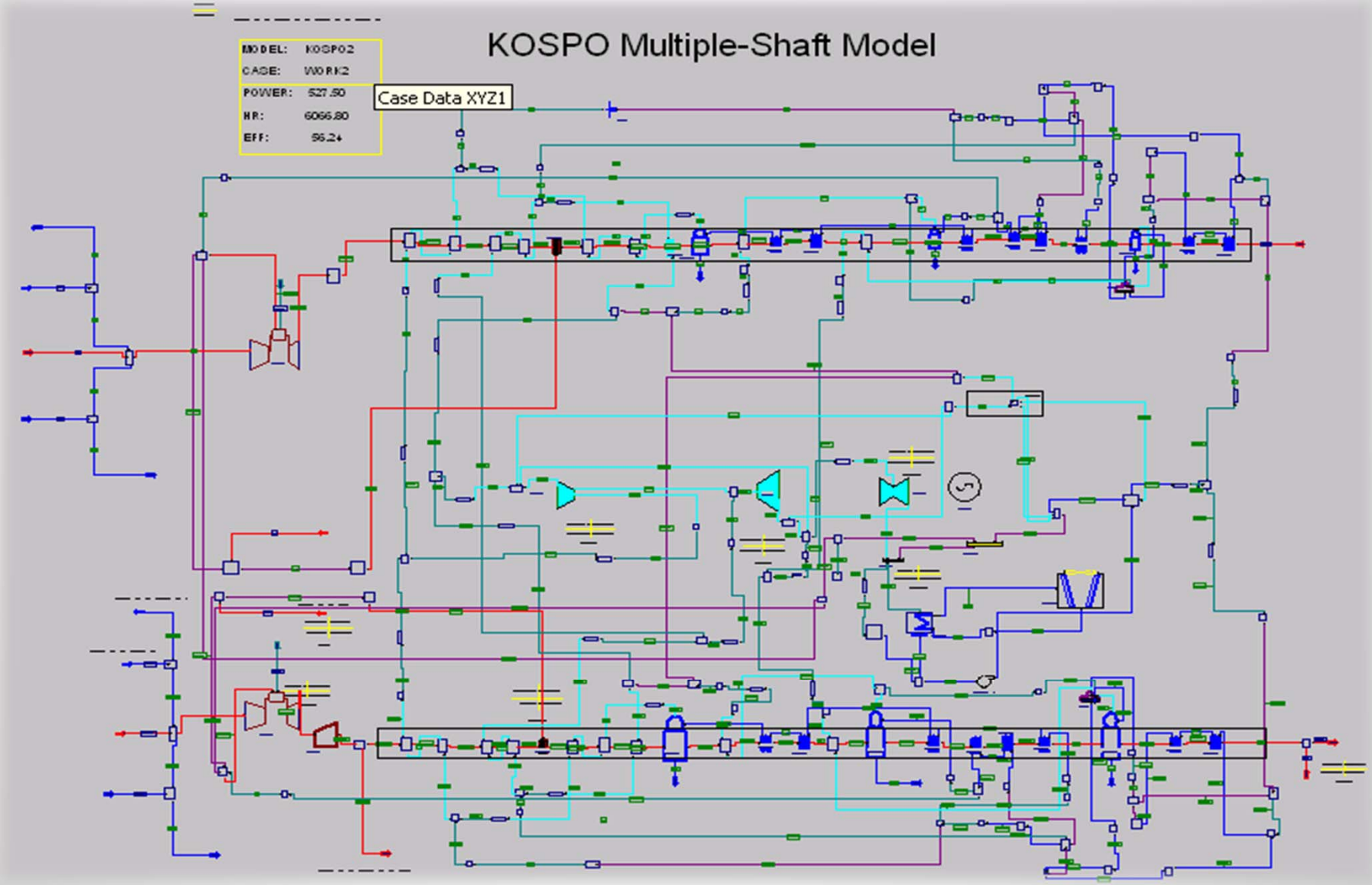
Experience of enesG worldwide in the Fossil Power Plants

more than 1.75% plant efficiency losses were recaptured in the field performance diagnostic testing of the 4 fossil units

No	Troubles	Actions	Eff. Loss Recapture	Effective Period
1	Drift of SH outlet temp. measurement for set point control (2 units)	Recalibrate and loop check during outage	More than 0.30%	continuous
2	Loss of credit from combustion air caused by additional intake for PA & FD fan (3 units)	Check the intake duct gasket to prevent entrance of the cold air	More than 0.60%	continuous
3	Excessive clearance of HP turbine diaphragm packing ring	Develop a guideline for optimization of packing clearance	0.11%	continuous
4	Malfunction of variable clearance packing (HP/IP mid-span packing)	To be determined	0.19%	continuous
5	Poor turbine back pressure control	Develop the CW pump operation profile for performance optimization	unaccountable	
6	Leakage of LP cleanup recirculation line shut-off valve	Optimizes the continuous vent	0.17%	continuous
7	Leakage of BFPT HP stop valve before and after seat drain line MOV	Inspect and repair during outage	0.45%	continuous
8	Valve leakage during normal operation in all units	Inspect and repair during outage	unaccountable	continuous
9	Steam trap malfunction during normal operation in all units	Inspect and repair during outage	unaccountable	continuous

③ Find AS-IS : AS-IS Basis Plant Performance Model

The thermal performance modeling is customized to the power plant hardware characteristics and tuned to current performance data and plant capabilities resulted from the field performance diagnostic testing.



③ Find AS-IS : AS-IS Basis Plant Performance Model

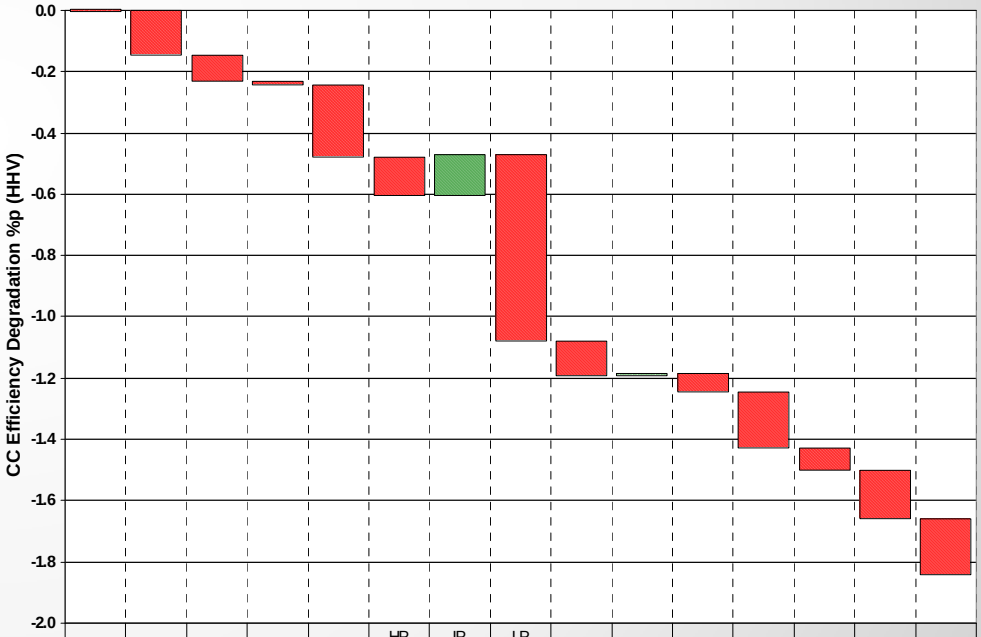
Performance Degradation Analysis (Sample for Combined Cycle Power Plant)

Determine overall plant degradation and recovery potential in Power Output and Efficiency through simulation of the AS-IS Basis Performance Model.

KOSPO Block #11
Estimated Combined Cycle Output Degradation Distribution

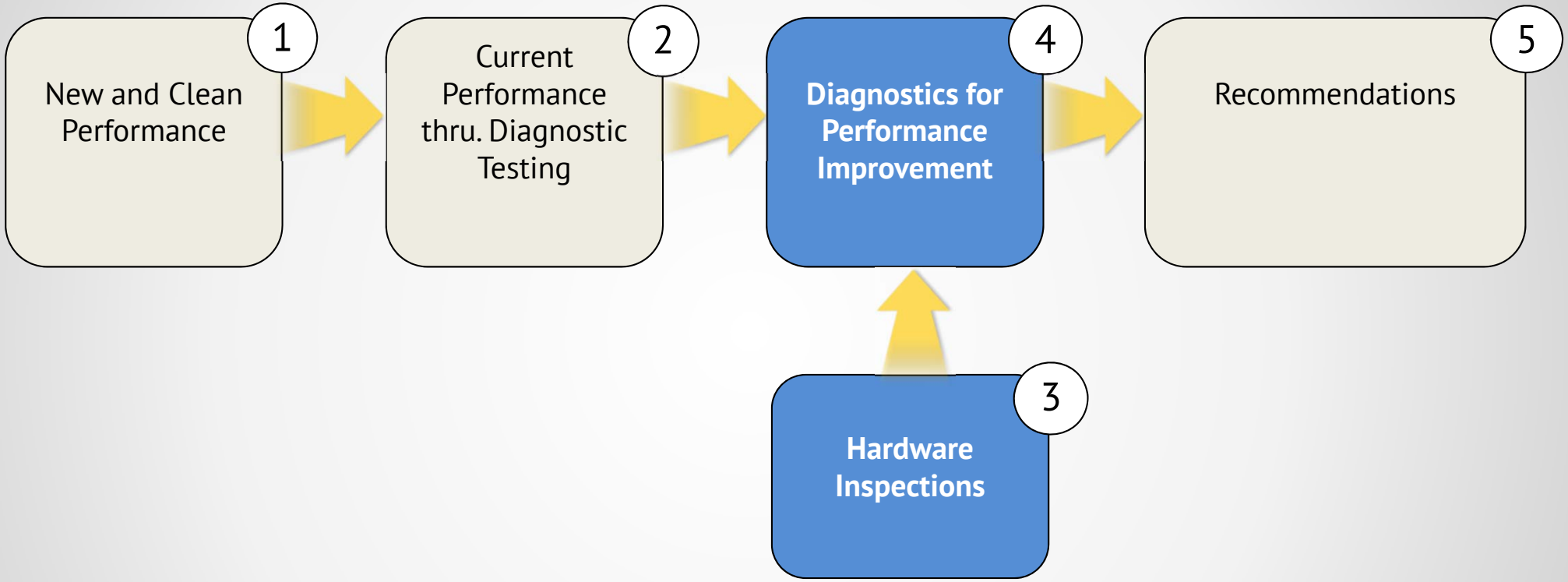
	New & Clean	GT13 Comp	GT13 Turbine	GT14 Comp	GT14 Turbine	HP Steam Turbine	IP Steam Turbine	LP Steam Turbine	HRSG13 HP	HRSG13 IP	HRSG13 LP	HRSG14 HP	HRSG14 IP	HRSG14 LP	Condenser
Start	0.0%	0.0%	-1.8%	-2.0%	-2.3%	-3.1%	-3.5%	-3.1%	-4.7%	-5.0%	-4.9%	-5.1%	-5.6%	-5.8%	-6.2%
End	0.0%	-1.8%	-2.0%	-2.3%	-3.1%	-3.5%	-3.1%	-4.7%	-5.0%	-4.9%	-5.1%	-5.6%	-5.8%	-6.2%	-6.6%

KOSPO Block #11
Esimated Combined Cycle Efficiency Degradation Distribution



	New & Clean	GT13 Comp	GT13 Turbine	GT14 Comp	GT14 Turbine	HP Steam Turbine	IP Steam Turbine	LP Steam Turbine	HRSG13 HP	HRSG13 IP	HRSG13 LP	HRSG14 HP	HRSG14 IP	HRSG14 LP	Condenser
Start	0.00	0.00	-0.15	-0.23	-0.24	-0.48	-0.61	-0.47	-1.08	-1.19	-1.18	-1.25	-1.43	-1.50	-1.66
End	0.00	-0.15	-0.23	-0.24	-0.48	-0.61	-0.47	-1.08	-1.19	-1.18	-1.25	-1.43	-1.50	-1.66	-1.84

④ Expect TO-BE : Feasibility Study for Retrofit

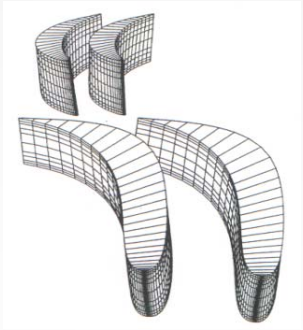


Hardware inspections of major plant components are carried out. Information collected is used in conjunction with operational and design data to determine recommendation for the performance improvement.

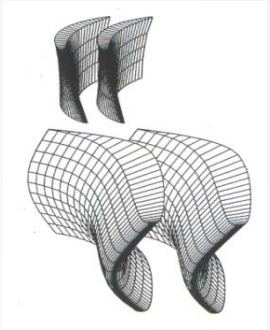
④ Expect TO-BE : Feasibility Study for Retrofit

- **Sample Case : Steam Turbine Upgrade in a Fossil Power Plant**

✓ Integral cover buckets(ICB's)
✓ High Efficiency Stage Design
✓ Root Sealing : Brush seals
✓ Tip Sealing : Advanced Seals

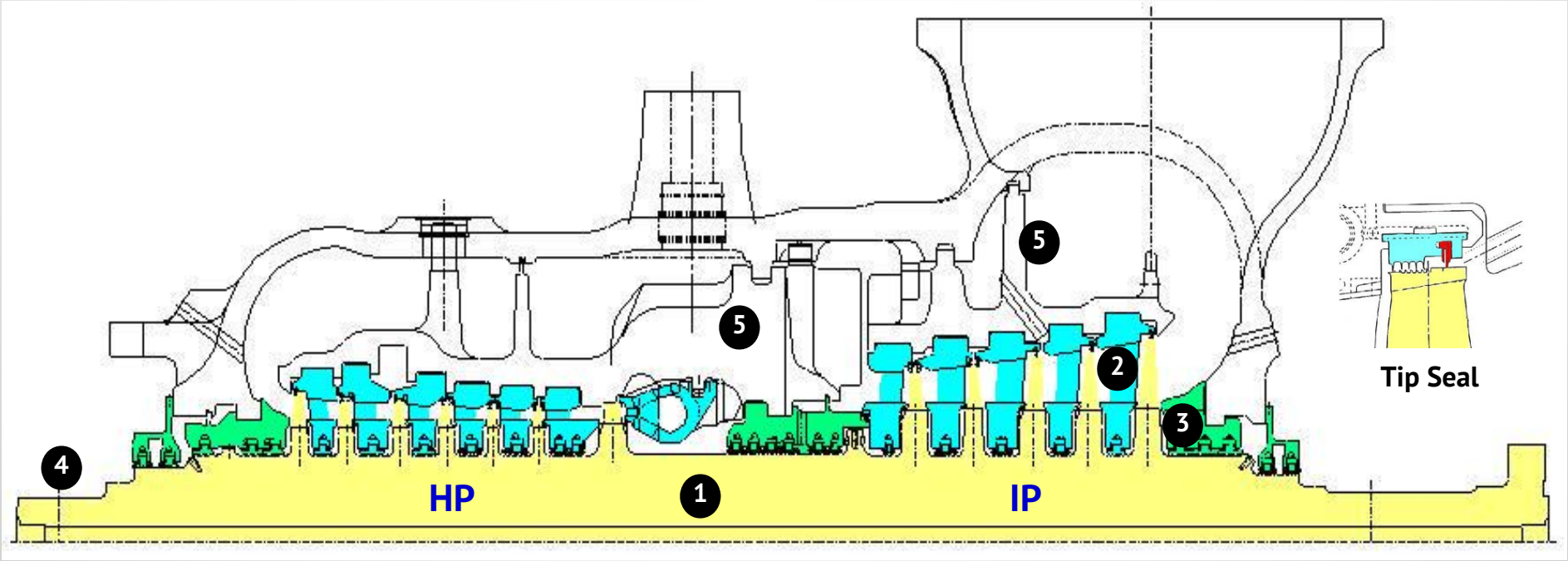


Advanced Vortex
HP Nozzle & Bucket



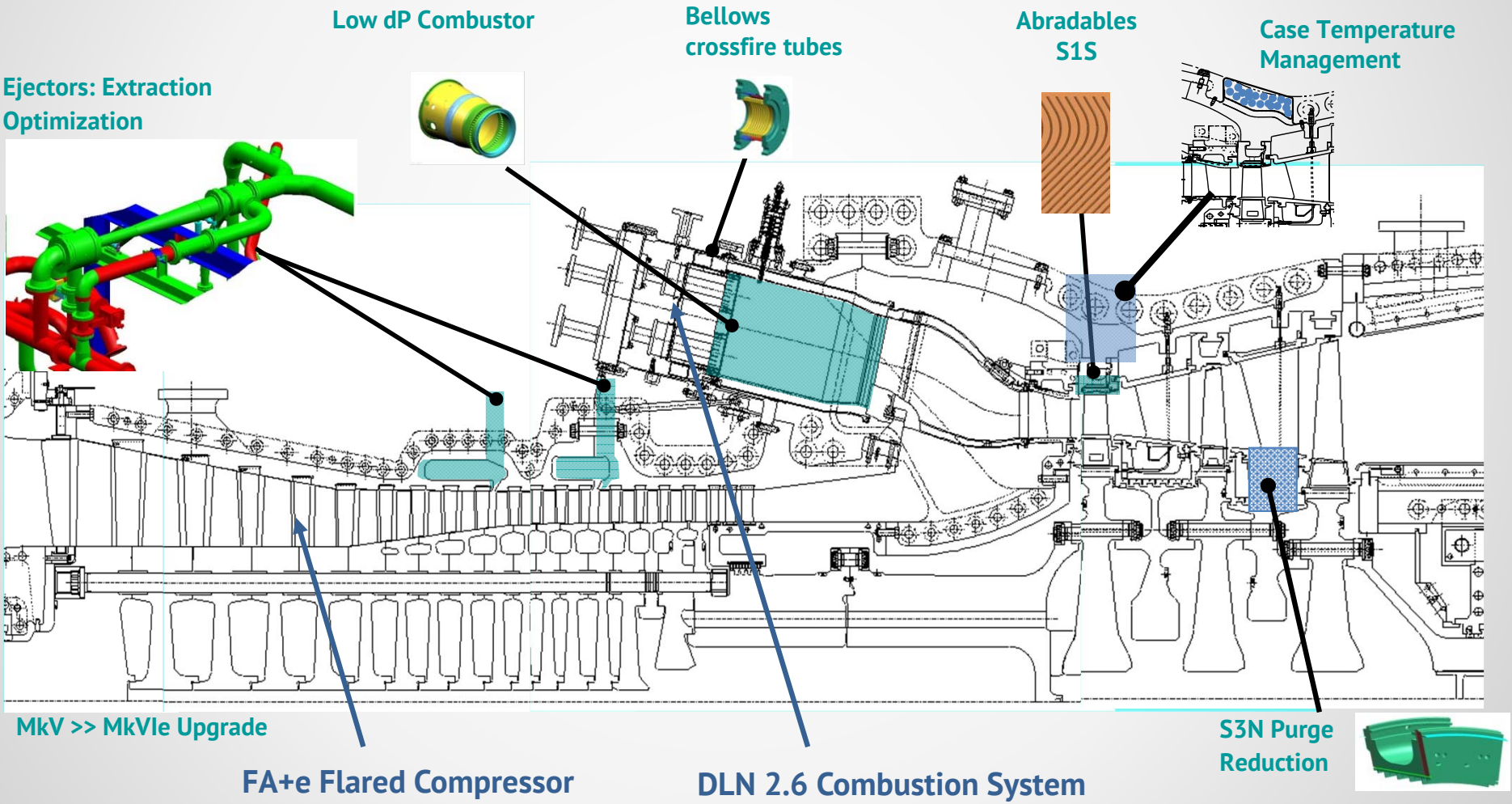
Advanced Vortex
IP Nozzle & Bucket

① Rotor & Bucket
② Diaphragm
③ Packing Casing
④ Journal Bearing
⑤ HP/IP Turbine



④ Expect TO-BE : Feasibility Study for Retrofit

- Sample Case : Gas Turbine Upgrades in a Combined Cycle Power Plant

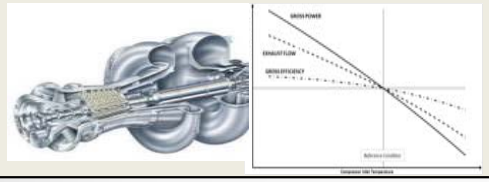


④ Expect TO-BE : Feasibility Study for Retrofit

- **Sampling Case : Gas Turbine Upgrade and Steam Cycle Add-On**

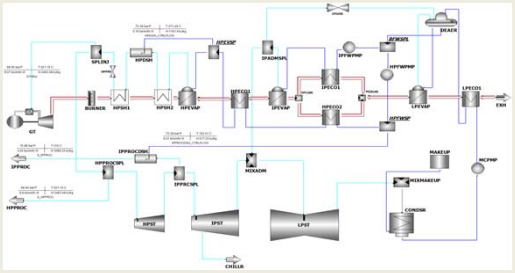
1

Upgraded Gas Turbine Modeling



3

CCPP Extension Modeling



4

CCPP Extension Modeling Test

5

Performance Optimization based on Thermo Economic Analysis

2

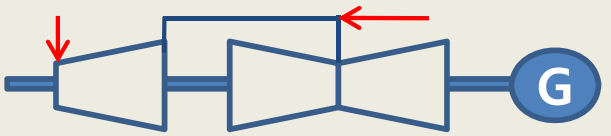
New Equipment Modeling

① **Combined Cycle Configuration (Preliminary)**

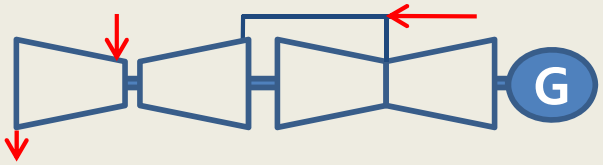
- 2 x GTG + 2 x HRSG + 1 x STG
- 3 x GTG + 3 x HRSG + 1 x STG
- 4 x GTG + 4 x HRSG + 1 x STG

② **HRSGs and STG configuration (Preliminary)**

- Dual Pressures (HP/LP)



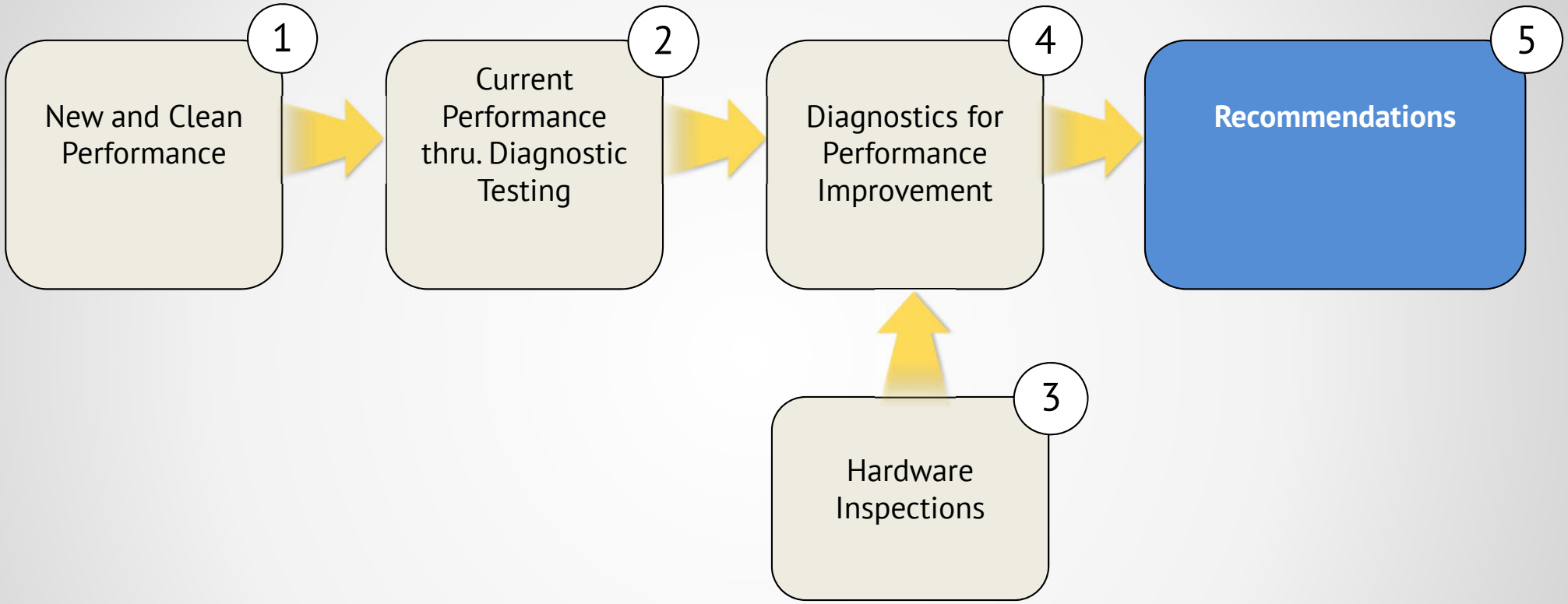
- Triple Pressures (HP/IP/LP)



③ **Condenser configuration**

- Steam Surface Condenser
- Air Cooled Condenser

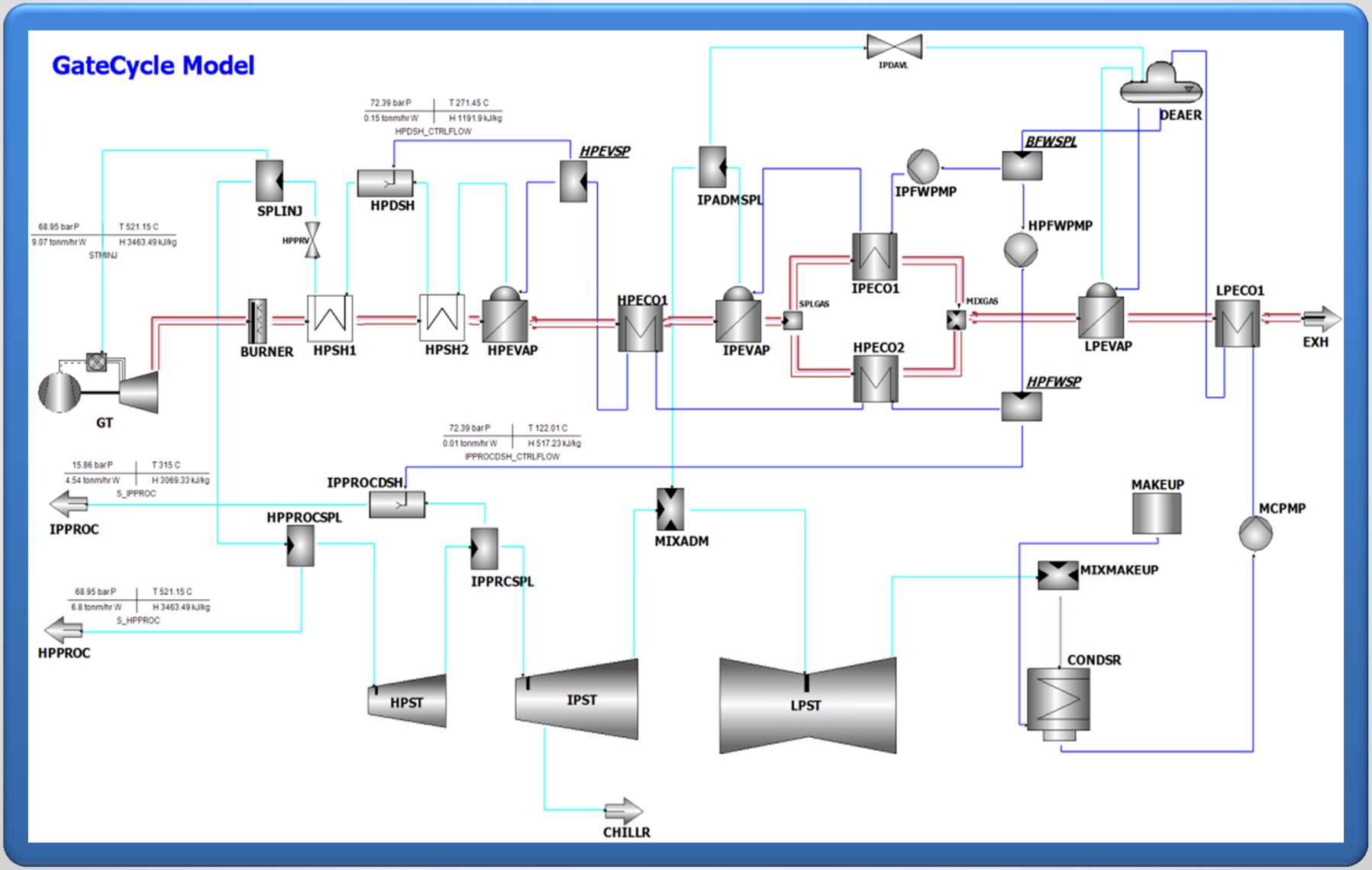
④ Expect TO-BE : Feasibility Study for Retrofit



Recommendations for performance improvement are issued based on current plant condition, existent equipment capabilities, and cost-benefit analysis.

④ Expect TO-BE : Feasibility Study for Retrofit

- TO-BE Basis Plant Performance Model (with new equipment)



④ Expect TO-BE : Feasibility Study for Retrofit

- **Performance Optimization based on Thermo-Economic Analysis**

✓ **Optimization process for Total Capital (investment) Costs**

Selecting optimal combination of equipment or components to minimize the Investment Costs.

✓ **Supporting the Investment Decision**

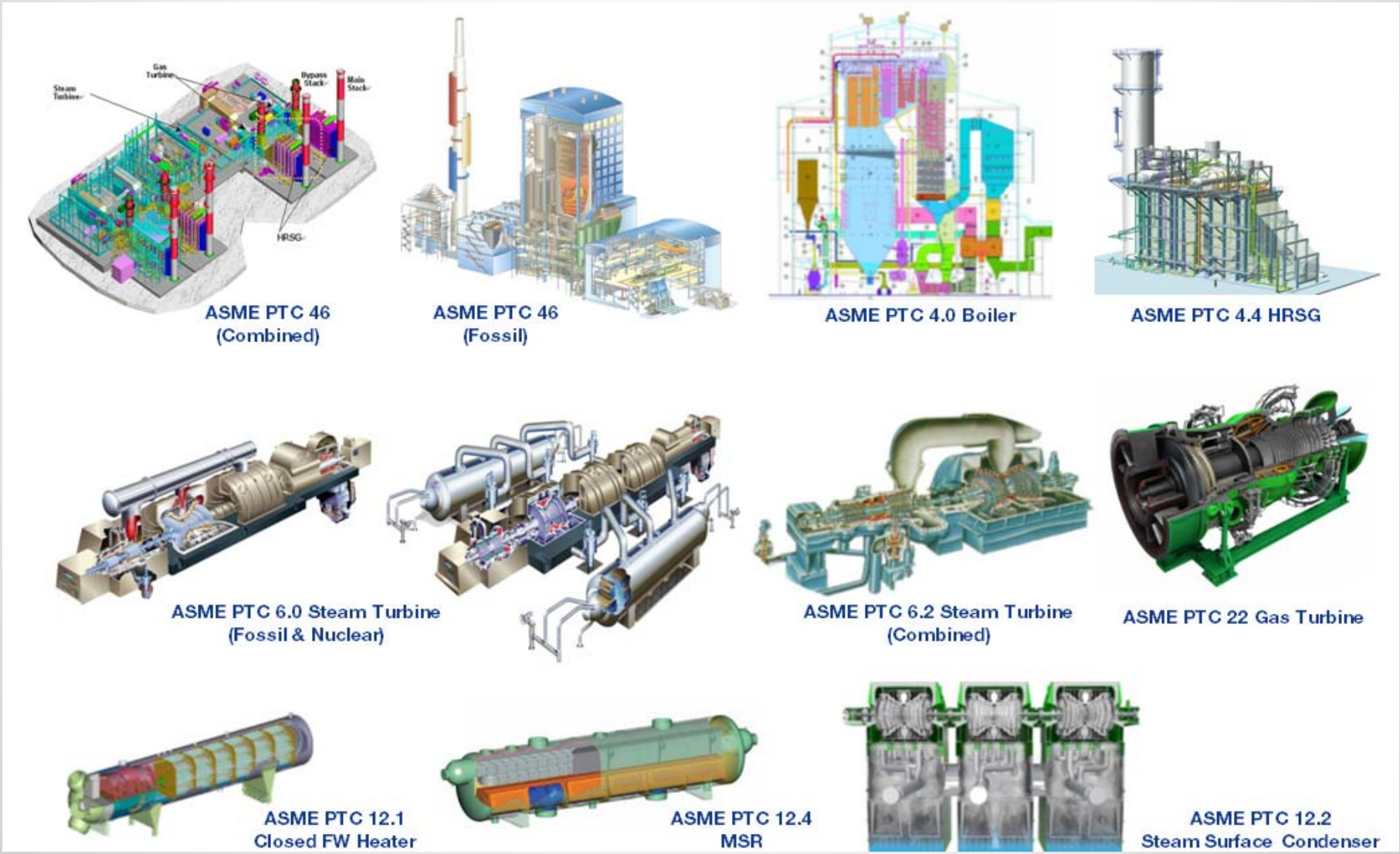
Evaluating the economic considerations by several possible methods e.g. the Cumulative Cash Flow Diagram, Payback Period, Average Rate of Return, Internal Rate of Return (*IRR*) according to Client's requirements.

✓ **Thermo Economic Analyses data requirement from Client**

Several financial data are needed e.g. Fuel Price, Electricity Price, Desired Rate of Return on Investment, planned Project Lifetime etc.

⑤ Verify TO-BE : Field Performance Acceptance Testing Service

Design and execution of performance acceptance testing for overall power plant or thermal island and individual equipment with a highest level of accuracy consistent with the best engineering knowledge and practice in the power industry.



Conclusion

Conclusion

① **Benefits of Plant Performance Improvement Program to the Owners are;**

- Improved plant efficiency – fuel cost savings
- Improved plant output – additional revenue
- Performance degradation recovery
- Short payback period
- Maximize use of original capital investment
- State of the art technology - increased Asset Value
- Lower Emissions (NOx, tonnes CO2/MWh)

② **The basis and very beginning activity of Plant Performance Improvement Program is to periodical Field Performance Diagnostic Testing which supports;**

- monitoring of plant performance degradation and effective ranking of components for plant performance recovery
- recapturing energy losses
- ideal plant operation for performance optimization

③ **Retrofit is cost-effective way to meet the increasing electric power demand in Asian countries, minimize environmental pollutions.**
For successful retrofit project, "Find AS-IS" and "Expect of TO-BE" is very important processes and should be executed by specialized engineering group.

Q & A