Standard of Geothermal Power Plant Design

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Presented by: *Joko Waluyo*

Training for Engineers on

Geothermal Power Plant

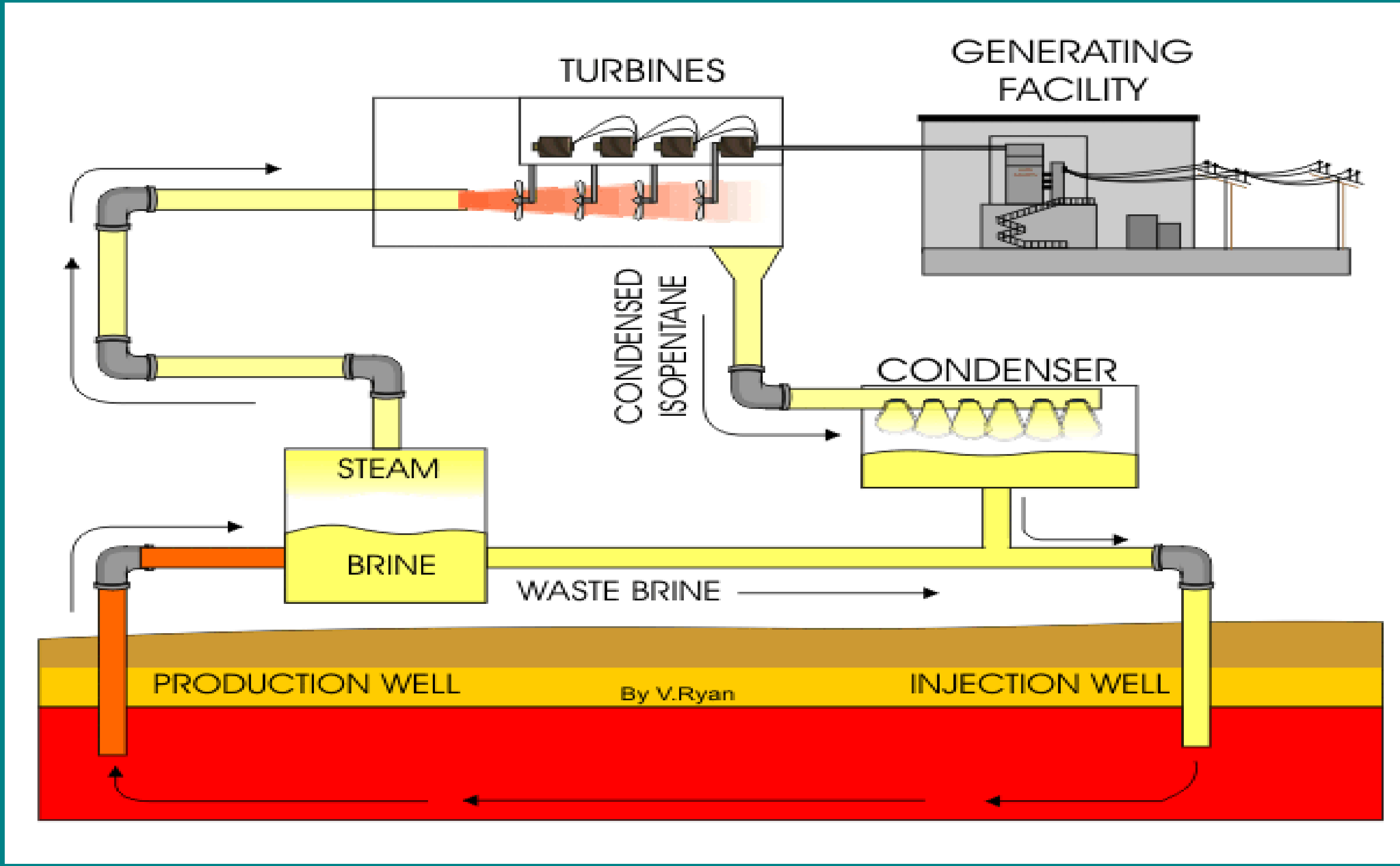
Yogyakarta, 9-13 October 2017

Geothermal Capacity Building Program Indonesia - Netherlands

Coverage of the presentation:

1. Geothermal Power Plant Design
2. Standard used for Geothermal Power Plant
3. Material Used for Geothermal Power Plant
4. Inspection/Maintenance of Geothermal Power Plant

CONCEPT OF GEOTHERMAL POWER PLANT



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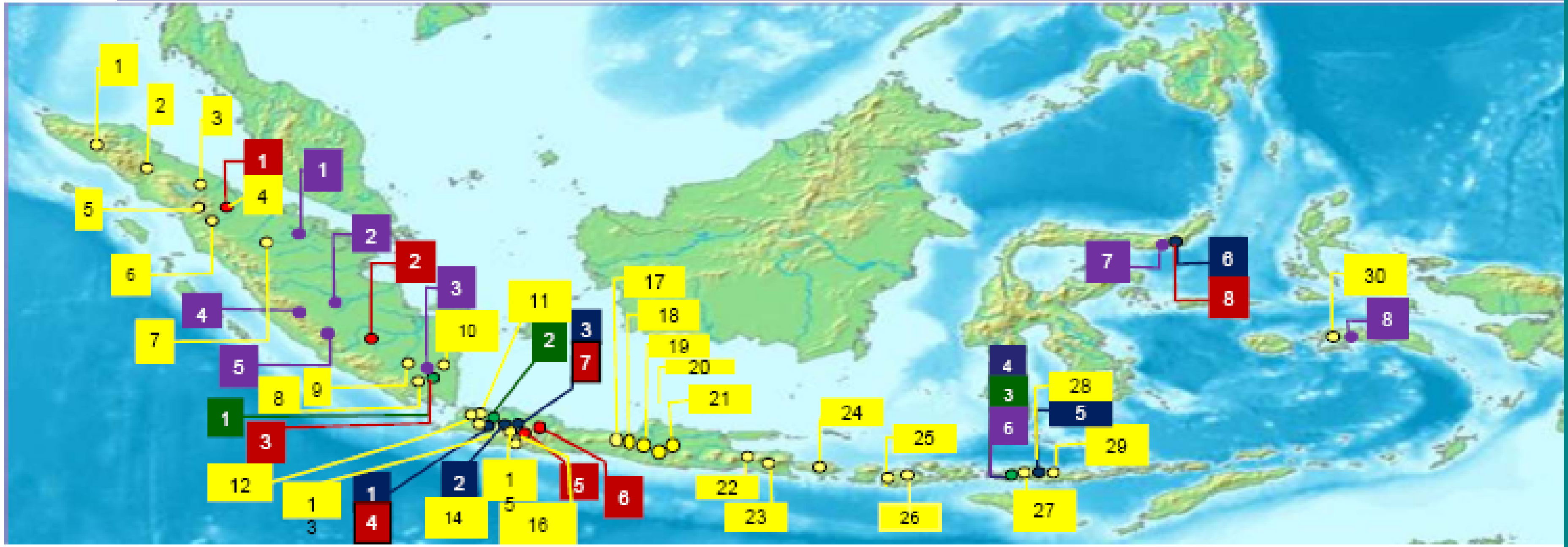
Fact and Figure Geothermal in Indonesia

Most of geothermal sites are located in Java-Bali Island and Sarulla of northern Sumatra. High temperature geothermal fields are associated with volcanic areas. Several projects take place in different Indonesian islands: 31 in Sumatra with 9.562 MW; 22 in Java with 5681 MW; 6 in Sulawesi with 1.565 MW and other eleven projects spread of Indonesia with 2859 MW. All of these high-enthalpy geothermal provinces located within the active volcanic areas are surrounded by large low-enthalpy resources with temperatures measuring around 150 °C. Indonesia deals the third position in the world ranking, has approximately 40% of the world's geothermal reserves with a potential of 28.100 MW, of which 1.197 MW have been exploited. Is the third largest emitter of greenhouse gases and aims to reduce emissions by 16% in 2025. 55 MW will be built and could be expanded to 200 MW in Merapi Sorik geothermal plant in North Sumatra. A study for the optimization of geothermal energy in the area, with 11 possible locations: Darajat, 117 MW at Wayang Windu, 40 MW at Lahendong, 60 MW at Kamojang, and 10 MW at Sibayak, reaching the total installed capacity of about 1.2 GW. (Bertani, 2010).

MAP OF GEOTHERMAL DEVELOPMENT



READY FOR EXPLORATION OR ON BIDDING STAGE

1. JABOI (10 MW)
2. SEULAWAH AGAM (55 MW)
3. S.MERAPI (240 MW)
4. SARULLA II (110 MW)
5. PUSUK BUKIT (110 mw)
6. SIPOHOLON (55 MW)
7. BONJOL(165 MW)
8. S. SEKINCAU (220 MW)
9. WAY RATAI (55 MW)
10. DANAU RANAU (110 MW)
11. C. CISUKARAME (50 MW)
12. RAWA DANO (110 MW)
13. G.ENDUT (55 MW)
14. W. WINDU 3&4 (220 MW)
15. T. PERAHU (170 MW)
16. TAMPOMAS (45 MW)
17. GUCI (55 MW)
18. BATU RADEN (220 MW)
19. NGEBEL/WILIS (165 MW)
20. UNGARAN (55 MW)
21. UMBUL TELOMOYO (55 MW)
22. IYANG ARGOPURO (55 MW)
23. IJEN (110 MW)
24. BEDUGUL (10 MW)
25. SEMBALUN (20 MW)
26. HU'U (20 MW)
27. SOKORIA (15 MW)
28. MATALOKO (15 MW)
29. ATADEI (5 MW)
30. JAILOLO (10 MW)

EXPLORATION STAGE

1. MUARA LABOH (220 MW)
2. RANTAU DADAP (220 MW)
3. RAJABASA (220 MW)
4. SUNGAI PENUH (110 MW)
5. HULULAIS (110 MW)
6. ULUMBU (5 MW)
7. KOTA MOBAGU (80 MW)
8. TULEHU (20 MW)

READY FOR EXPLOITATION

1. SARULLA I (330 MW)
2. LUMUT BALAI (220 MW)
3. ULUBELU 3&4 (110 MW)
4. KAMOJANG 5&6 (90 MW)
5. CIBUNI (10 MW)
6. KARAHA BODAS (140 MW))
7. LAHENDONG 5&6 (40 MW)

CONSTRUCTION STAGE (117,5 MW)

1. ULUBELU 1&2 (110 MW)
2. PATUHA (120 MW)
3. ULUMBU (7,5 MW)

PRODUCTION STAGE (1201 MW)

1. KAMOJANG (200 MW)
2. WAYANG WINDU (220 MW)
3. DIENG (60 MW)
4. ULUMBU (2,5 MW)
5. MATALOKO (1,5 MW)
6. LAHENDONG (80 MW)

Power Plant Design Parameter

Resources:

1. Steam conditions: Optimum turbine inlet steam pressure. Gas (% NCG) in steam.
2. Size (thickness and areal extent), and long term capacity, and natural recharge.
3. Temperature and pressure of deep resource fluid.
4. Chemical composition (liquid and gas phase) of deep fluid.
5. Geology, stratigraphy, lithology and geothermal reservoir properties (faults, fractures, formation porosity, mineral alteration types and age, type of permeability).
6. Reservoir permeability.
7. Thickness of production/injection zones.
8. Well productivity/injectivity.
9. Two phase zones.
10. Reservoir response to production/injection.
11. Natural state modelling, computer simulation of reservoir, and model predictions.
12. Reservoir monitoring and management.

Power Plant Design Parameter

- **Accessibility**
  1. Topography of resource area.
  2. Remoteness from population centres.
  3. Closeness to nature parks and environmentally restricted areas.
- **Market**
  1. Size, type and security of market.
  2. Proximity of market.
  3. Accessibility to existing power transmission lines, substations.
- **Permits etc.**
  1. Resource concessions.
  2. Exploration permits.
  3. Drilling permits.
  4. Development permits.
  5. Environmental Impact Assessment.
  6. Building and other permits.
- **Pre and post investment studies, business plan**

Geothermal Power Generation Worldwide

	Installed capacity MW_e	Annual electricity produced GWh/year	Number of units
Australia	1.1	0.5	2
Austria	1.4	3,8	3
China	24	150	8
Costa Rica	166	1,131	6
El Salvador	204	1,422	7
Ethiopia	7.3	10	2
France (Guadeloupe)	16	95	3
Germany	6.6	50	4
Guatemala	52	289	8
Iceland	575	4,597	25
Indonesia	1,197	9,600	22
Italy	843	5,520	33
Japan	536	3,064	20
Kenya	167	1,430	14
Mexico	958	7,047	37
New Zealand	628	4,055	33
Nicaragua	88	310	5
Papua New Guinea	56	450	6
Philippines	1,904	10,311	56
Portugal	29	175	5
Russia	82	441	11
Thailand	0.3	2	1
Turkey	82	490	5
USA	3,093	16,603	210
TOTAL	**10,715**	**67,246**	**526**

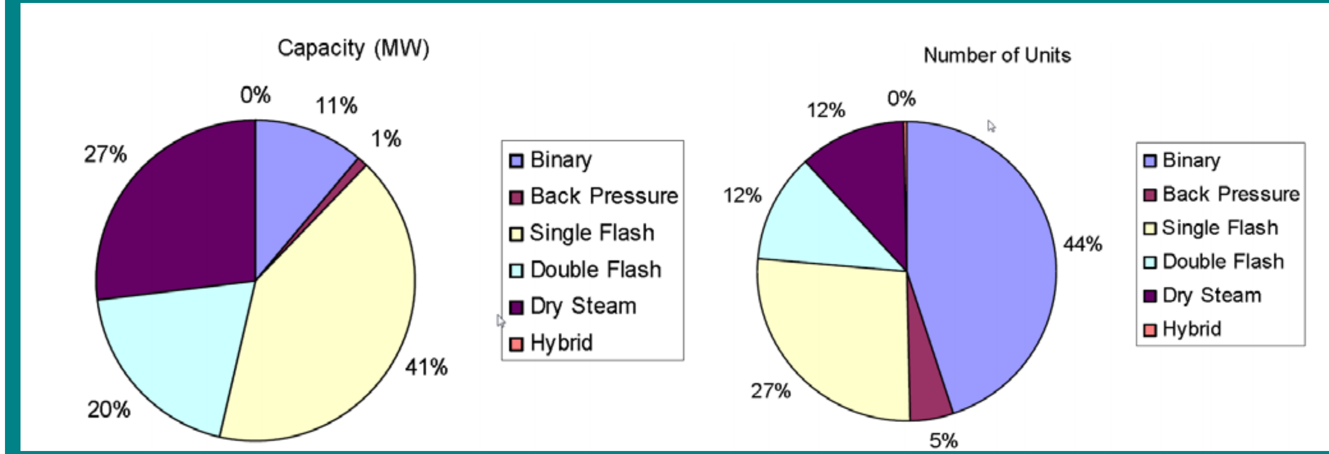
Worldwide Geothermal Power Plant Installed (Bertani, 2010)

Geothermal Power Plant Installed Since 1998

Country	MW	No. Units	MW/Unit	Plant Types[1]
United States	2850	203	14.0	DS,1F,2F,B,H
Philippines	1848	64	28.9	1F,2F,H
Mexico	743	26	28.6	1F,2F,H
Italy	742	na	—	DS,2F,H
Indonesia	589.5	15	39.3	DS,1F
Japan	530	18	29.4	DS,1F,2F
New Zealand	364	na	—	1F,2F,H
Costa Rica	120	4	30	1F
El Salvador	105	5	21	1F,2F
Nicaragua	70	2	35	1F
Iceland	50.6	13	3.9	1F,2F,H
Kenya	45	3	15	1F
China	28.78	13	2.2	1F,2F,B
Turkey	21	1	21	1F
Portugal (Azores)	16	5	3.2	1F,H
Russia	11	1	11	1F
Ethiopia	8.5	2	4.2	H
France (Guadeloupe)	4	1	4	2F
Argentina	0.7	1	0.7	B
Australia	0.4	1	0.4	B
Thailand	0.3	1	0.3	B
Total	**8147.78**			

[1] DS=Dry Steam, 1F=Single Flash, 2F=Double Flash, B=Binary, H=Hybrid
Note: A unit is defined as a turbine-driven generator. Data from Ref. [4] and various other sources.

Worldwide Geothermal Power Plant Installed (Bertani, 2010)

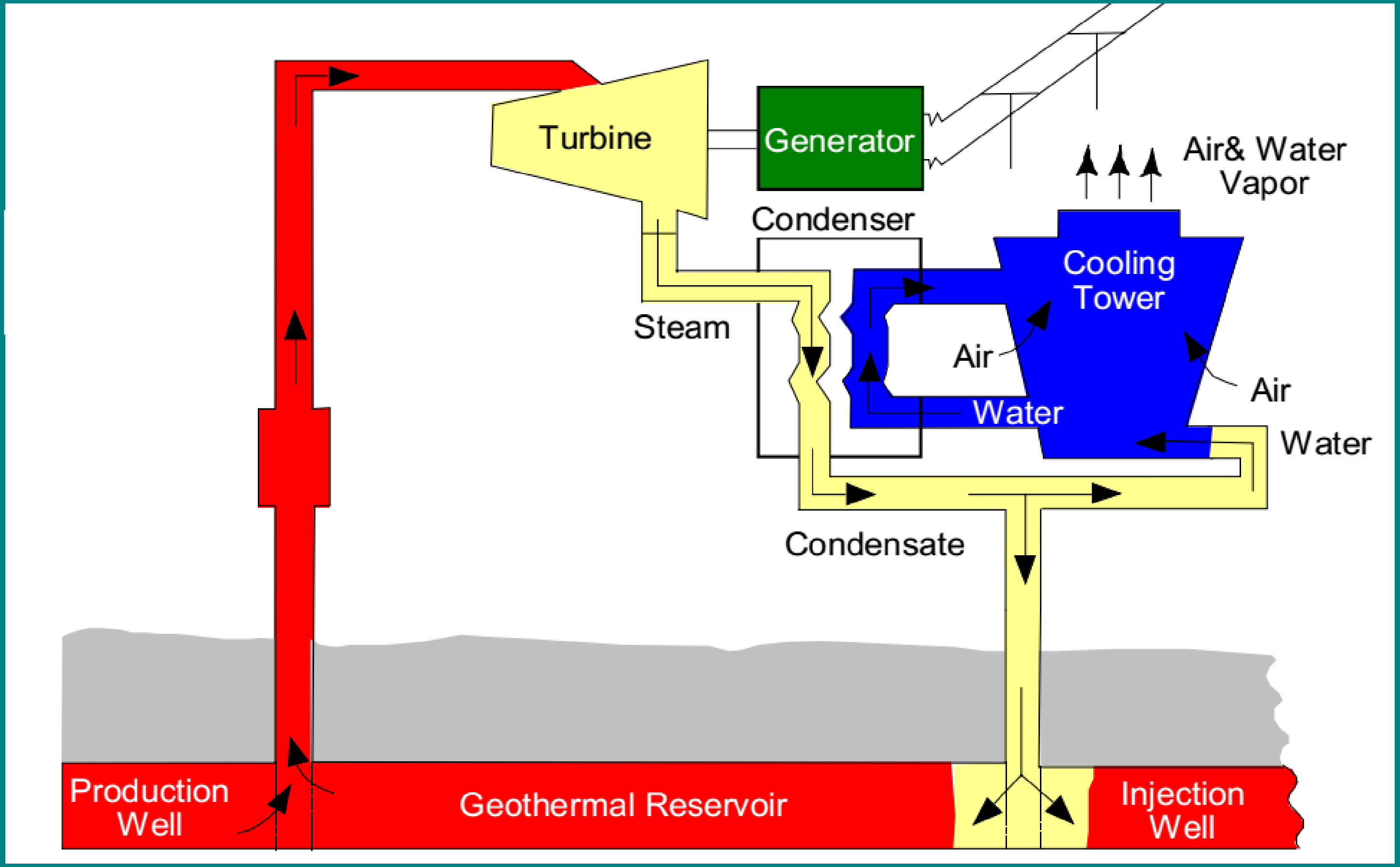


Distribution Worldwide by type

TECHNOLOGY OF GEOTHERMAL POWER PLANT

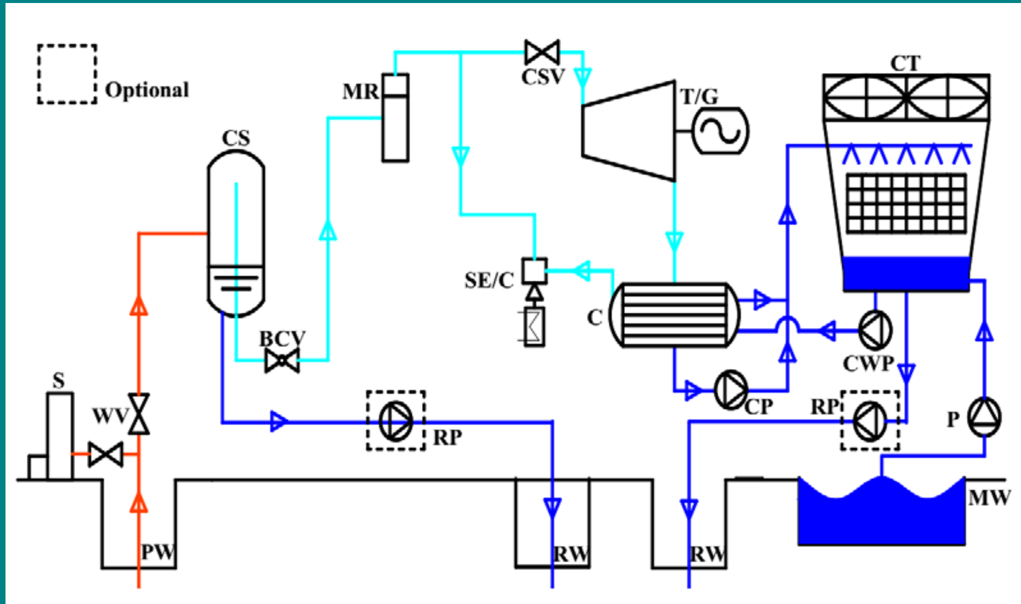
- Dry Steam
- Single Flash
- Double Flash
- Organic Rankine Cycle (Basic Binary)
- Back Pressure
- Hybrid Conversion System

Dry Steam

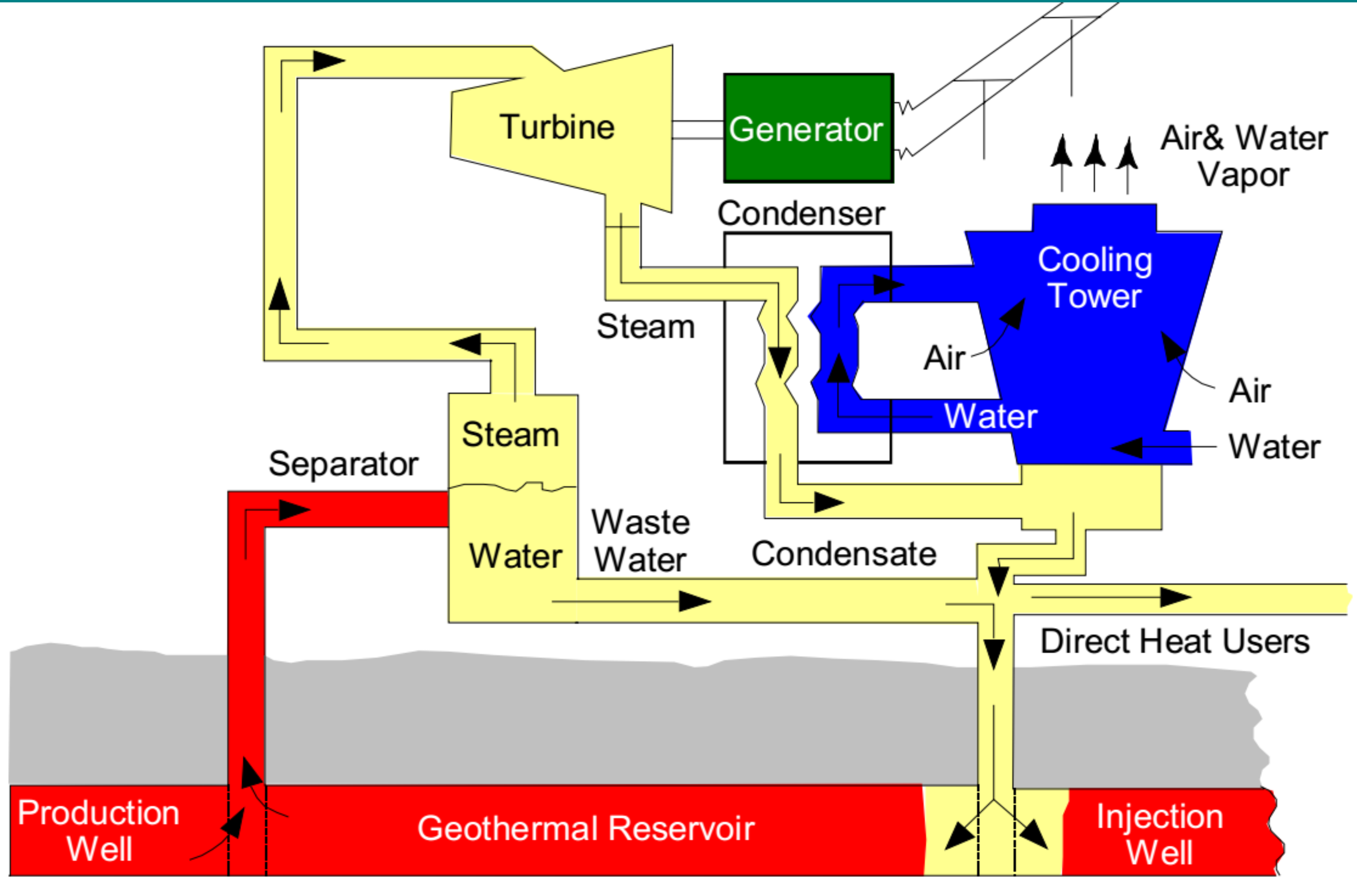


Turbine
Generator
Air& Water
Vapor
Condenser
Cooling
Tower
Steam
Air
Air
Water
Water
Condensate
Production
Well
Geothermal Reservoir
Injection
Well

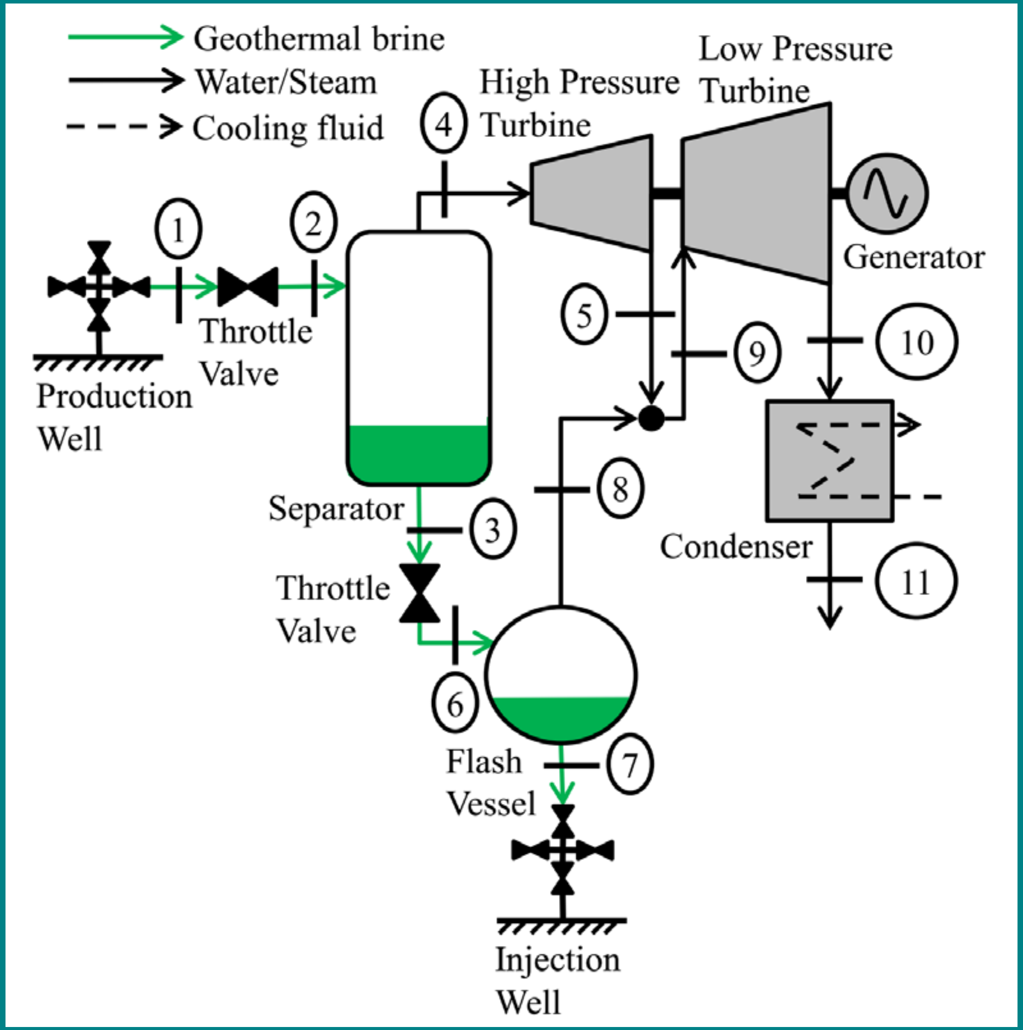
SINGLE FLASH

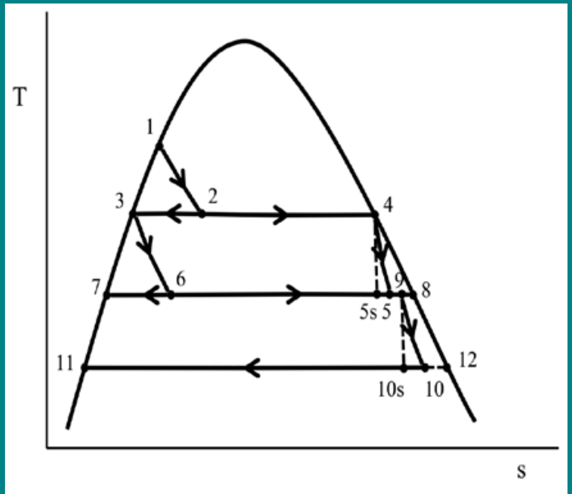


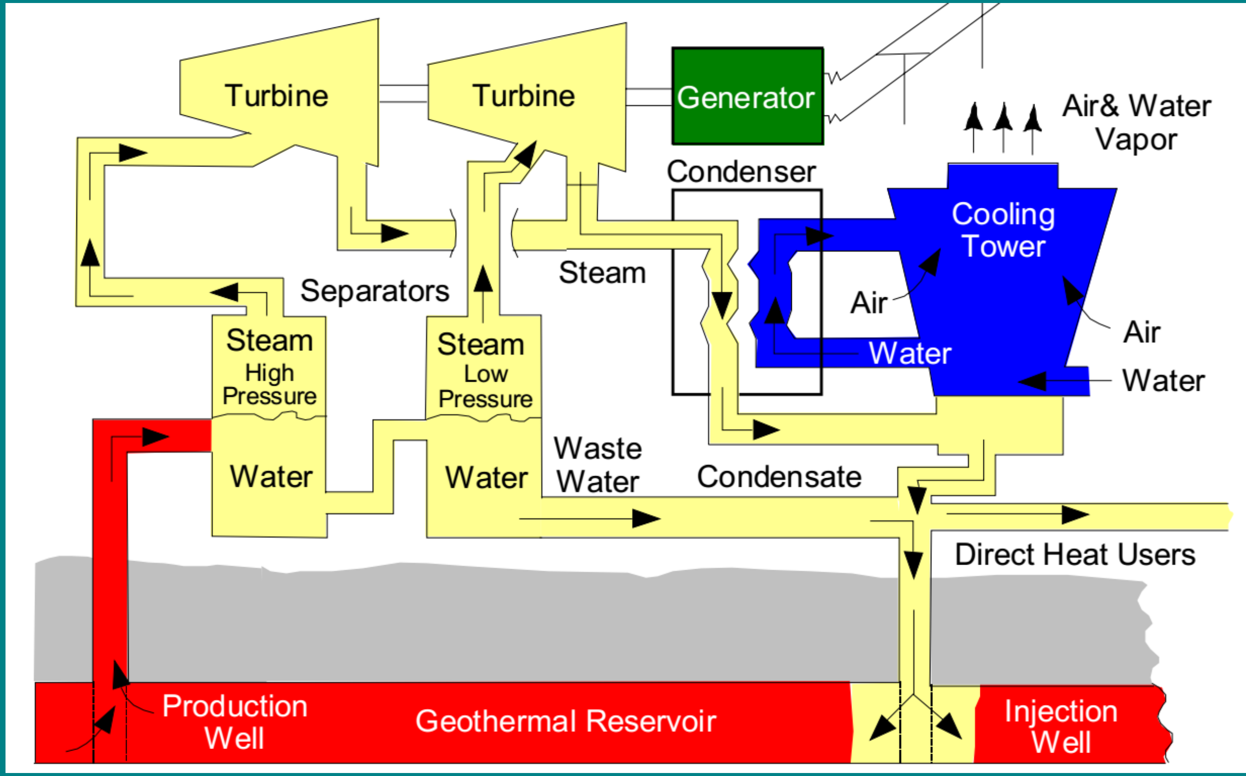
PW	Production well	WV	Wellhead valve	S	Silencer
CS	Cyclone separator	BCV	Ball check valve	MR	Moisture remover
CSV	Control / stop valve	T/G	Turbine / generator	SE/C	Steam ejector/condenser
C	condenser	CT	Cooling tower	CWP	Cooling water pump
CP	Condensate pump	RP	Reinjection pump	RW	Reinjection well
P	Pump	MW	Make-up water		



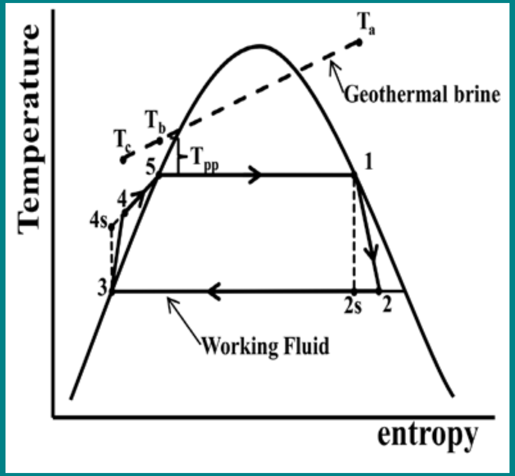
DOUBLE FLASH

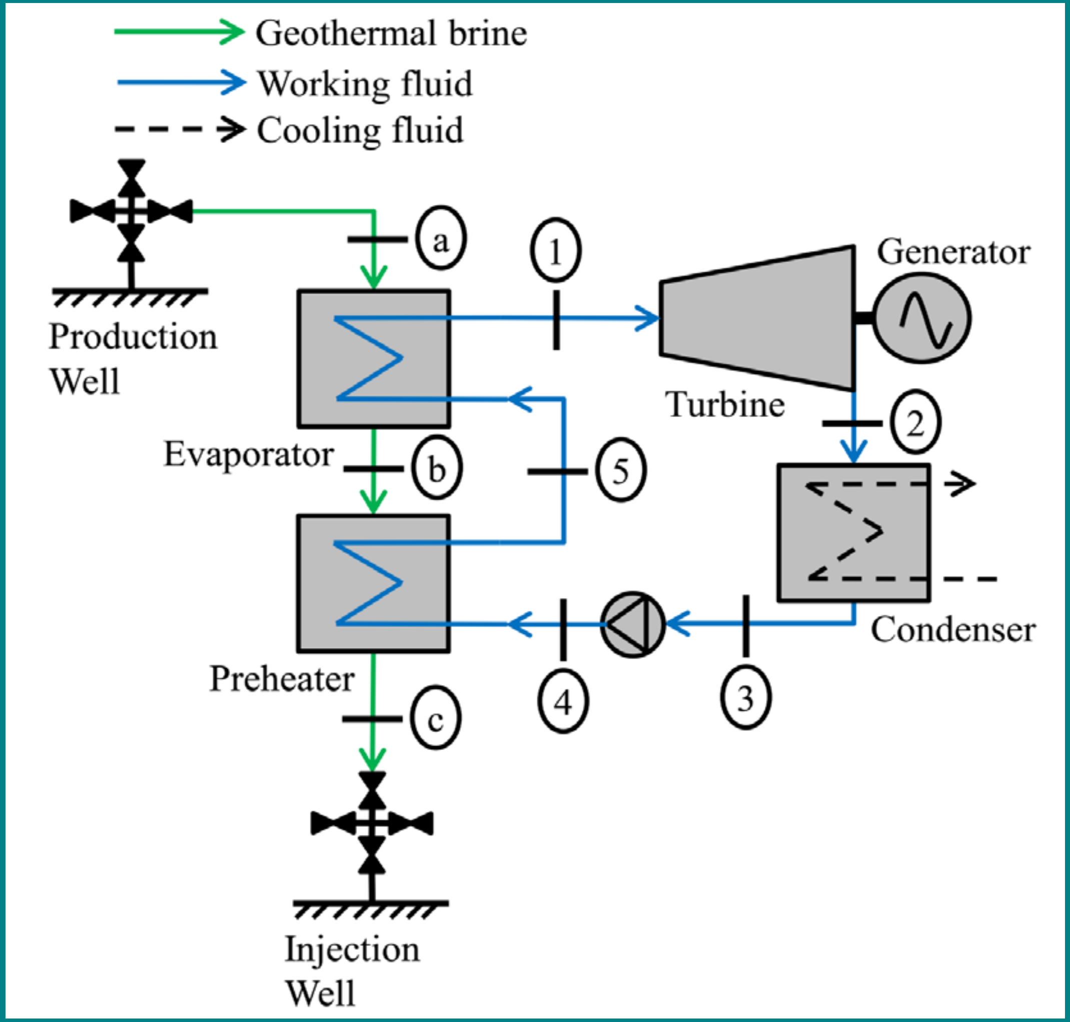


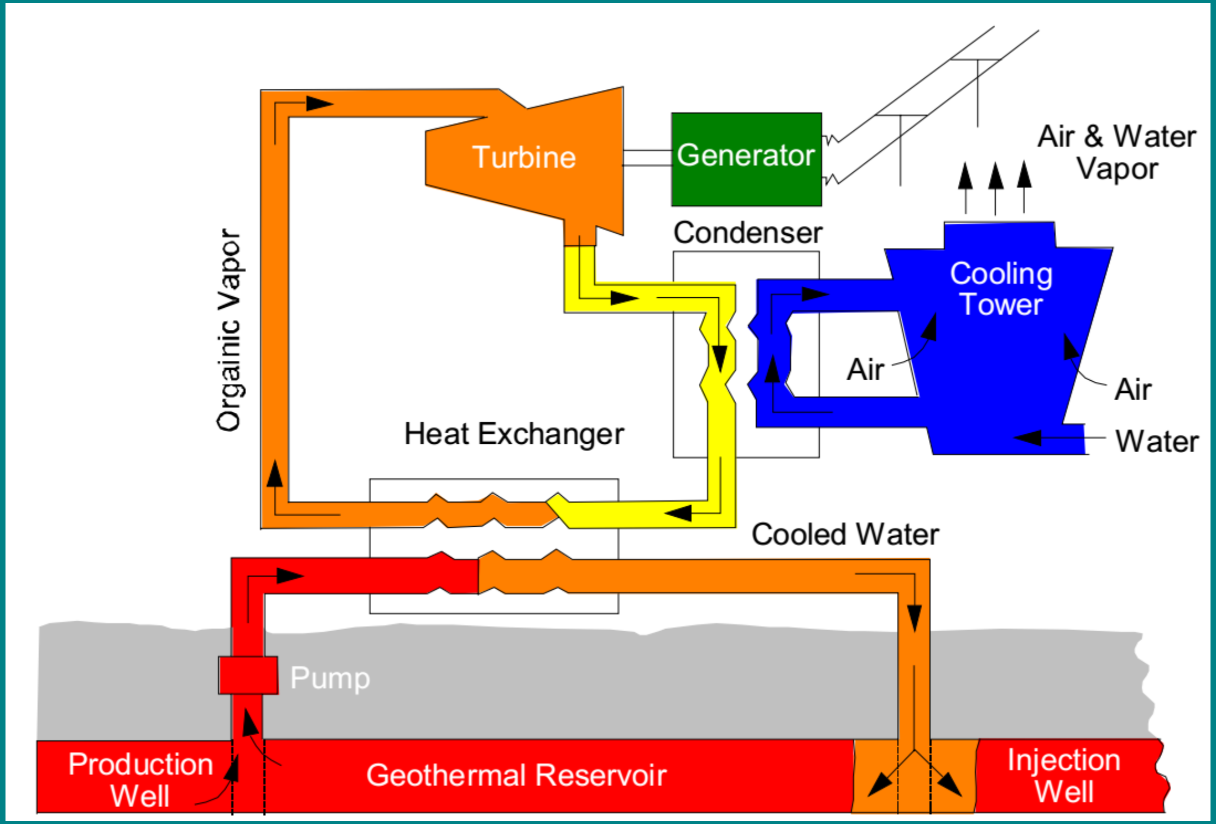




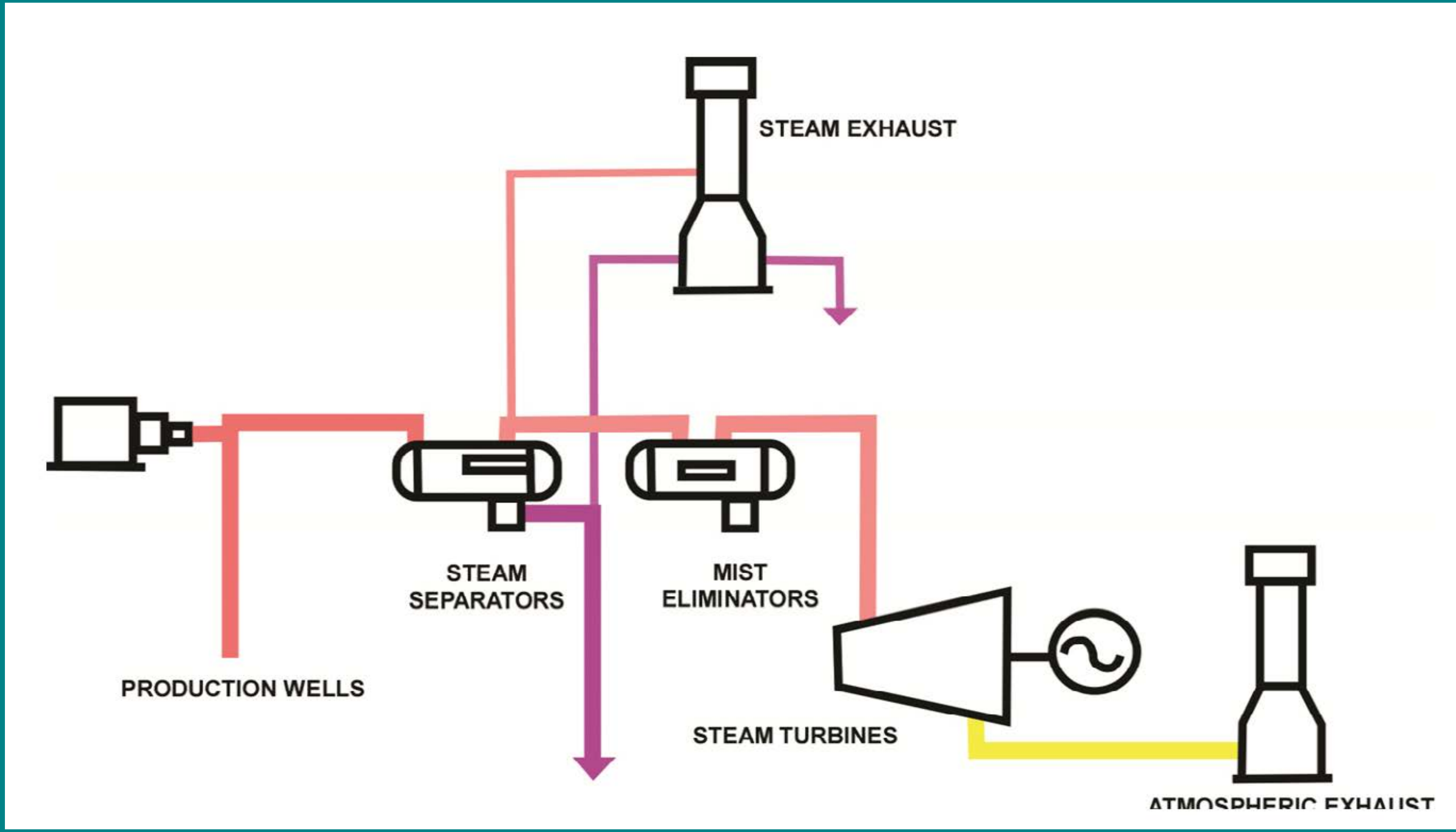
ORGANIC RANKINE CYCLE



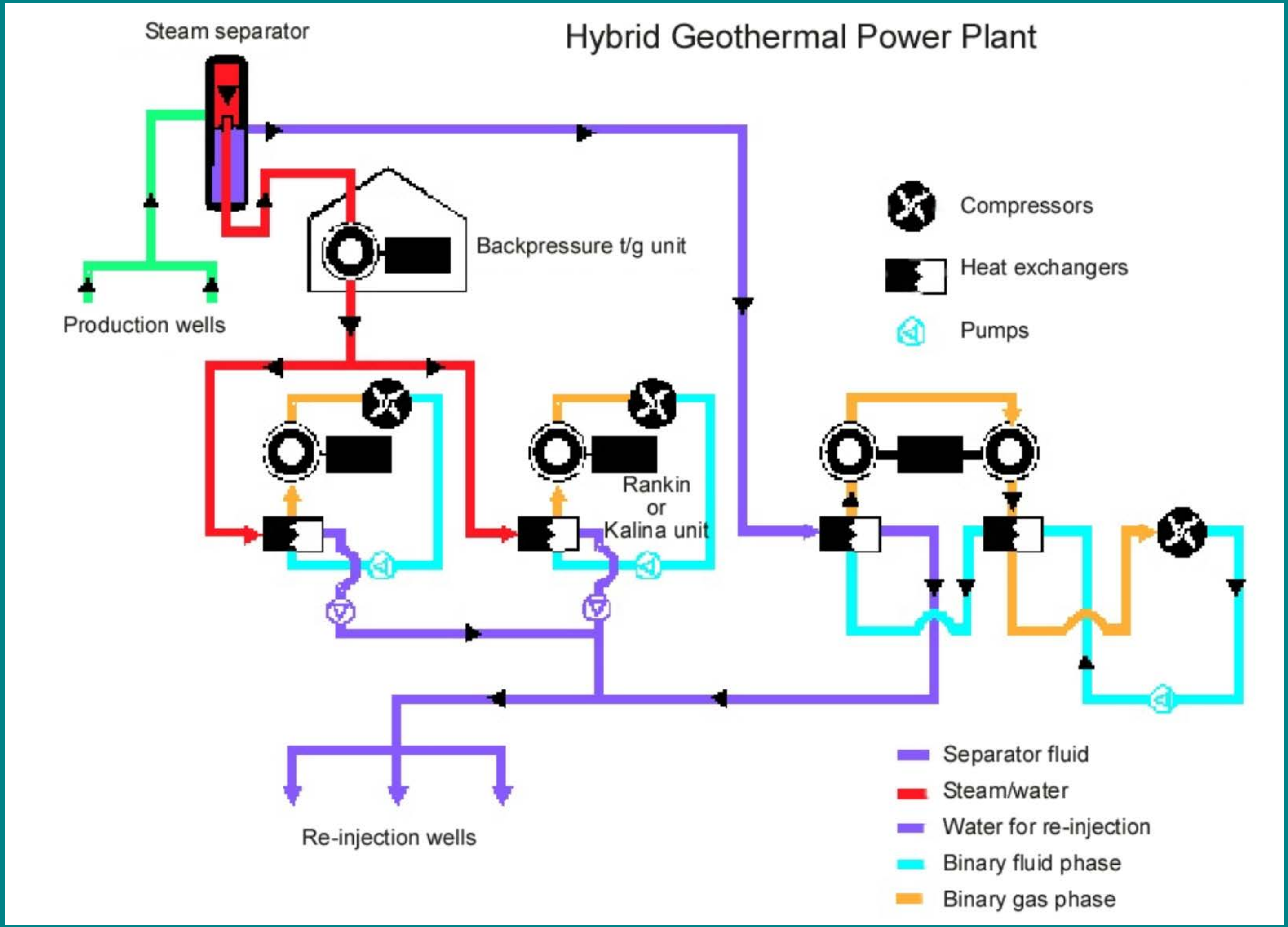




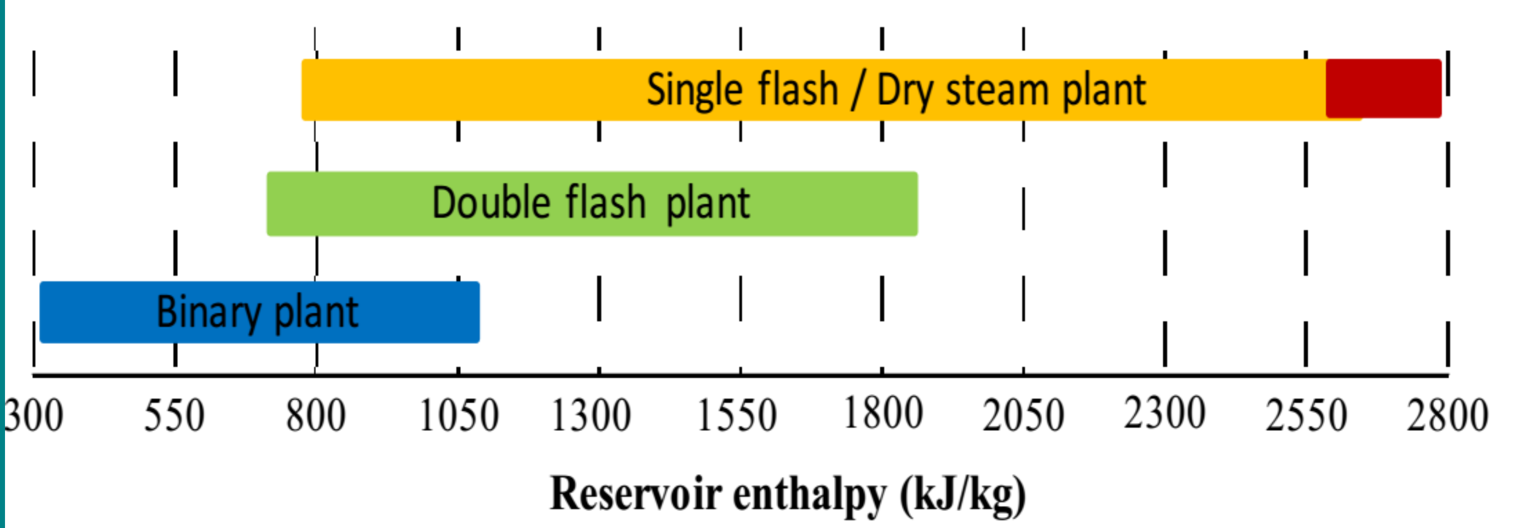
Back Pressure



Hybrid System



Differentiation of power plant



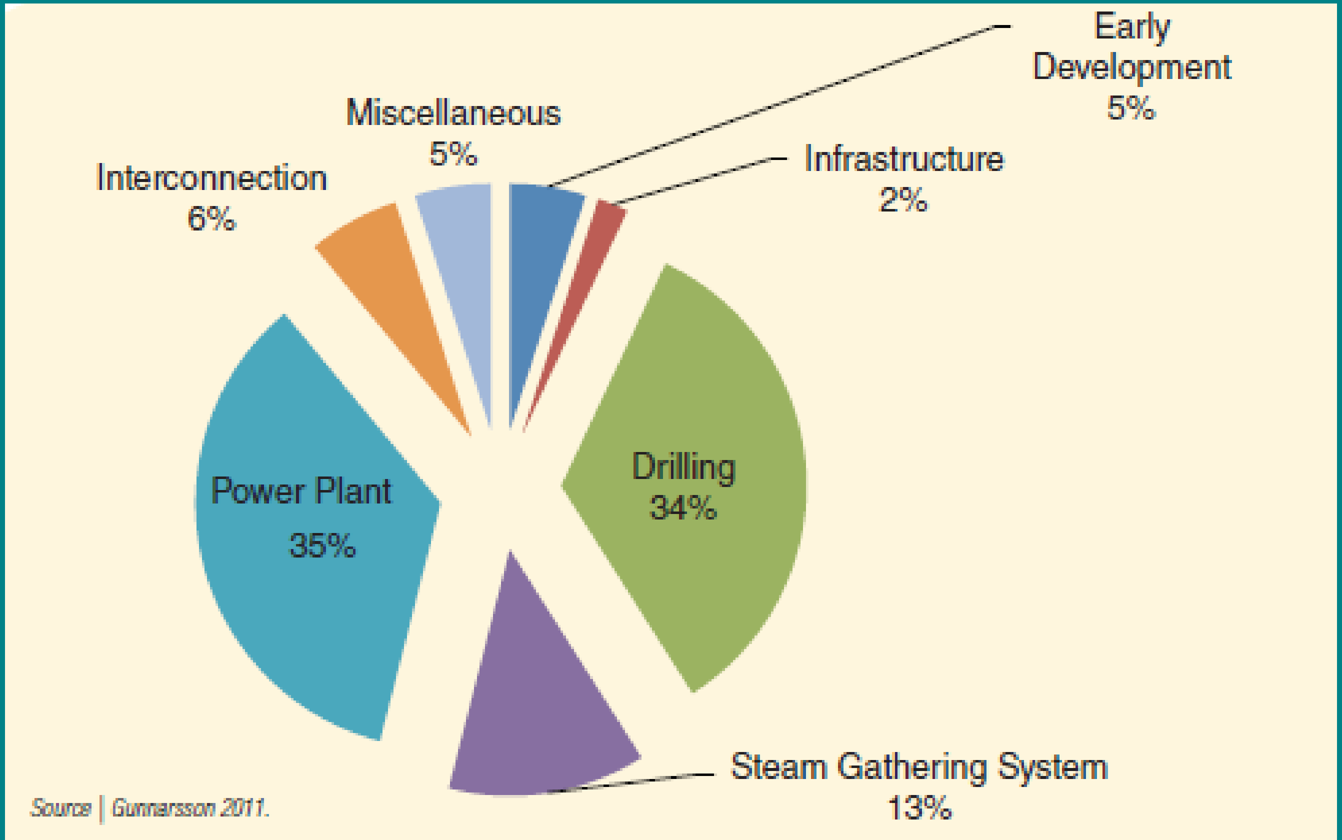
Type of power plant	Conversion efficiency	R^2
General geothermal plant	7.8795ln(h) – 45.651	0.76
Single flash and dry steam plant	8.7007ln(h) - 52.335	0.78
Double flash plant	10.166ln(h) – 61.680	0.856
Binary plant	6.6869ln(h) - 37.930	0.672

Economics of Geothermal Power Plant

The Cost associated with building and operating a geothermal powerplant vary widely and depend on such factors:

- Resource type (steam or ot water)
- Resource temperature
- Reservoir productivity
- Powerplant type (single-flash,binary,etc.)
- Environmental regulations
- Cost of capital
- Cost of labor

INVESTMENT COST BREAKDOWN OF GEOTHERMAL POWER PLANT



Major Equipment Geothermal Power Plant

Equipment	Type of Energy Conversion System			
	Dry Steam	Single Flash	Double Flash	Basic Binary
Steam and/or Brine Supply:				
Downhole pumps	No	No (Poss.)	No (Poss.)	Yes
Wellhead valves & controls	Yes	Yes	Yes	Yes
Silencers	Yes	Yes	Yes	No
Sand/particulate remover	Yes	No	No	Yes
Steam piping	Yes	Yes	Yes	No
Steam cyclone separators	No	Yes	Yes	No
Flash vessels	No	No	Yes	No
Brine piping	No	Yes	Yes	Yes
Brine booster pumps	No	Poss.	Poss.	Poss.
Final moisture separator	Yes	Yes	Yes	No
Heat Exchangers:				
Evaporators	No	No	No	Yes
Condensers	Yes (No)	Yes (No)	Yes	Yes
Turbine-Generator & Controls:				
Steam turbine	Yes	Yes	Yes	No
Organic vaopr turbine	No	No	No	Yes
Dual-admission turbine	No	No	Yes	No
Control system	Yes	Yes	Yes	Yes
Plant Pumps:				
Condensate	Yes (No)	Yes (No)	Yes	Yes
Cooling water circulation	Yes (No)	Yes (No)	Yes	Yes
Brine injection	No	No (Poss)	Yes (No)	Yes
Noncondensable Gas Removal System:				
Steam-jet ejectors	Yes	Yes	Yes	No
Compressors	Poss.	Poss.	Poss.	No
Vacuum pumps	Poss.	Poss.	Poss.	No
Cooling Towers:				
Wet type	Yes (No)	Yes (No)	Yes	Poss.
Dry type	No	No	No	Poss.

Notes: Yes=generally used, No=generally not used, Poss.=possibly used under certain circumstances.

Major Equipment Geothermal Power Plant (GHC Bulletin, 1999)

Capital Cost for U.S Geothermal Plant Since (year)

Type/Plant Name	Year	Power, MW_n	Cost, $/kW
Direct Steam			
PG&E Geysers:			
Unit 1	1960	11	174
Unit 8	1972	53	109
Unit 13	1980	133	414
NCPA-1	1983	110	780
Single Flash			
Blundell	1984	20	3000 (e)
Steamboat Hills	1988	12	2500 (e)
Double Flash			
Desert Peak	1985	9	2000 (e)
Beowawe	1985	16	1900 (e)
Heber	1985	47	2340 (e)
Dixie Valley	1988	66	2100 (e)
Brady Hot Springs	1992	24	2700 (e)
Binary			
Empire	1987	3	4000 (e)
Stillwater	1989	12	3085 (e)
SIGC	1993	33	3030 (e)

Capital O&M Cost for Small Binary Geothermal Plant Since (1993)

Net Power, kW	Resource Temperature, C 100 — Capital Cost, $/kW	120	140	Total O&M Cost $/year
100	2,535	2,210	2,015	19,100
200	2,340	2,040	1,860	24,650
500	2,145	1,870	1,705	30,405
1,000	1,950	1,700	1,550	44,000

SOME DATA REQUIRED FOR GEOTHERMAL POWER PLANT DESIGN

- Plant power output
- Production well data
- Injection well data
- Ambient temperature
- Ambient pressure
- Water source
- Waste water standard
- Area availability
- Earth quake
- Wind

STANDARD

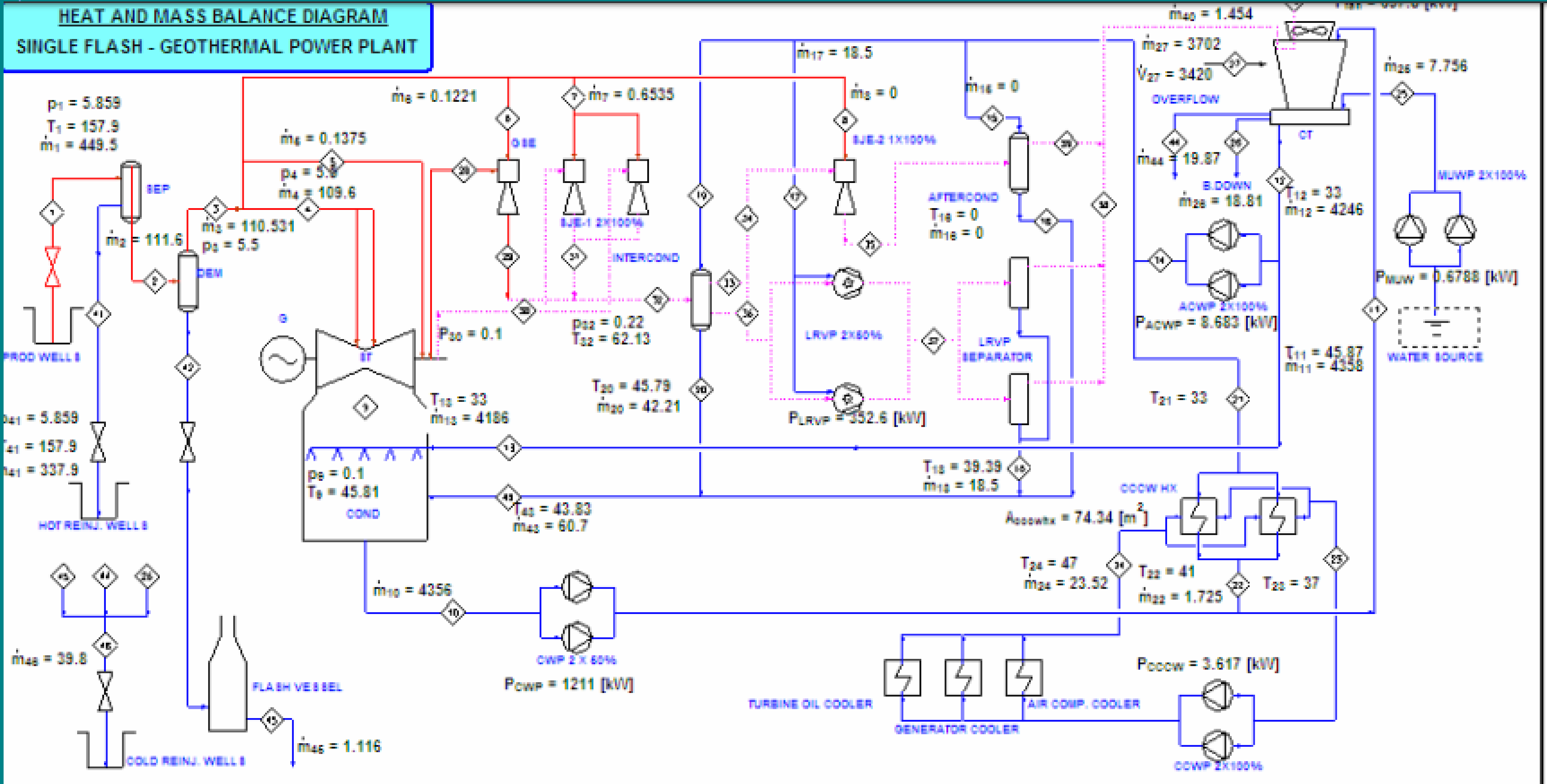
- International standard
- National government regulation
- Local government regulation
- Company/internal regulation/standard

TYPICAL SCOPE OF GPP EPCC CONTRACT

GPP=Geothermal Power Plant
EPCC=Engineering Procurement Construction Commissioning

- "The scope of the Contract shall cover the Facilities on a turnkey basis comprising a single unit Geothermal Power Plant described herein and the related fluid collection and reinjection system(FCRS) with a net capacity at the high voltage terminals of 60MW. The scope of work includes design, manufacture, inspection and/or testing before shipment, packing for shipment, shipment, insurance, custom clearance, land transportation from port of destination to the Site, offloading at Site, construction of civil works, storing of equipment, erection, painting, setting to work, pre commissioning(including inspections, testing and certifications by third parties in accordance with the national regulations), commissioning, performance testing and warranty for the Facilities. The power plant and relevant FCRS shall be designed for an operating life of 30 years."

PROCESS FLOW DIAGRAM OF THE GPP



STREAM ID		1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17
FLUID		STEAM	STEAM	STEAM	STEAM	STEAM	STEAM	STEAM	STEAM	STEAM	WATER	WATER	WATER	WATER	WATER	WATER	WATER
PRESSURE	bar a	5.859		5.5	5.5	1.3	5.5	5.5	5.5	0.1						0	
TEMP.	°C	157.9		155.5	155.5		155.5	155.5	155.5	45.81	45.81	45.87	33	33	33	0	33
FLOW	kg/s	449.5	111.6	110.531	109.6	0.1375	0.1221	0.6535	0	109.6	4356	4358	4246	4186	0	0	18.5

STREAM ID		18	19	20	22	23	24	25	26	27	30	40	41	43	44	45	46
FLUID		WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	AIR	NCG	NCG	WATER	WATER	WATER	WATER	WATER
PRESSURE	bar a	0.0715									0.1		5.859				
TEMP.	°C	39.39	33	45.79	41	37	47	25	33	27.1	36	39.39	157.9	43.83	33		33
FLOW	kg/s	18.5	41.29	42.21	1.725	1.725	23.52	7.756	18.81	3702	1.452	1.454	337.9	60.7	19.87	1.116	39.8

PERTAMINA GEOTHERMAL ENERGY

UNITED NATIONS UNIVERSITY GEOTHERMAL TRAINING PROGRAMME

INPUT :: AMBIENT DATA

$T_{wb,1}$ = 25 [C]
RH_1 = 0.85
Alt = 1100 [m] p_1 = 0.8879 [bar]

INPUT :: GEO FLUID DATA

T_{res} = 270 [C] h_{res} = 1185 [kJ/kg]
NCG = 0.01325

INPUT :: DESIGN CRITERIA

STEAM SUPPLY

P_{sep} = 5.859 [bar]
Di_{pipe} = 1.029 [m]
$Pipeline_{number}$ = 2
L_{pipe} = 3000 [m]

PLANT PARAMETERS

$P_{turbine,in}$ = 5.5 [bar]
$\dot{W}_{turbine,gross}$ = 55000 [kW]
$\dot{W}_{turbine,gross,init}$ = 55000 [kW]
P_{cond} = 0.10000 [bar]
Gas Rem Sys SJE-LRVP
$T_{approach}$ = 8 [C] (CT)
$T_{drop,hotside}$ = 10 [C] (CCWHX)
$T_{rise,coldside}$ = 8 [C] (CCWHX)

HOT REINJECTION

$Pipe_{sep,brine,number}$ = 2
Di_{hot} = 0.5747 [m]
L_{hot} = 3000 [m]
$\Delta_{H,elev,hot}$ = 100 [m]

COLD REINJECTION

$Pipe_{cold,reinj,number}$ = 2
Di_{cold} = 0.2545 [m]
L_{cold} = 1000 [m]
$\Delta_{H,elev,cold}$ = 100 [m]

OUTPUT

STEAM SUPPLY PIPELINE

$\Delta_{p,pipeline}$ = 0.2437 [bar]
$v_{st,dsg,max}$ = 35.81 [m/s]
$v_{st,act}$ = 21.45 [m/s]
P_{margin} = 0.1153 [bar]

PLANT

$\dot{W}_{turbine,net}$ = 52725 [kW]
$P_{aux,tot}$ = 2275 [kW]
$Ratio_{P,aux,tot}$ = 0.04136
SSC_{net} = 7.547
$\eta_{utilization,net}$ = 0.4476

HOT REINJECTION PIPELINE

P_{sep} = 5.859 [bar]
$\Delta_{p,g,hot}$ = 8.913 [bar]
$\Delta_{p,f,hot}$ = 8.001 [bar]
$P_{margin,hot}$ = 6.771 [bar]
$v_{sep,brine}$ = 0.4116 [m/s]

COLD REINJECTION PIPELINE

$\Delta_{p,g,cold}$ = 9.748 [bar]
$\Delta_{p,f,cold}$ = 2.883 [bar]
$P_{margin,cold}$ = 6.865 [bar]
$v_{cold,reinj}$ = 0.1001 [m/s]

Calculate

Developed by Hanifah Bagus S./ UNU GTP 2010 - Indonesia

GEO CAP

EPCC Scope of work

- Engineering
- Procurement
- Construction
- Commissioning

More detail scope of work & supply

- Design
- Manufacture
- *Inspection and/or testing before shipment*
- *Packing for shipment*
- Shipment
- Insurance
- Custom clearance
- *Land transportation from port of destination to the Site*
- Off loading at Site
- Construction of civil works
- Storing of equipment
- Erection
- Painting
- Setting to work
- *Pre commissioning(including inspections, testing and certifications by third parties in accordance with the Indonesian regulations)*
- Commissioning
- *Performance testing and warranty for the Facilities*

GEOTHERMAL POWER PLANT

CONSTRUCTION PHASE

- Source : http://www.thorndoncook.com/documents/StarttoSteam-Plant-Design.pdf

AREA DIVISION OF WORK&SUPPLY

- FCRS (FLUID COLLECTION AND REINJECTION SYSTEM)
- GPP (GEOTHERMAL POWER PLANT)

FLUID COLLECTION AND REINJECTION SYSTEM

- Separator
- Hot brine pump
- Cold condensate pump
- Piping
- Valve
- Emergency diesel generator
- Compressed air system
- Air conditioning system
- Fire fighting and fire detection system

FLUID COLLECTION AND REINJECTION SYSTEM

- Separator

STANDARD	
ASME	• ASME Section II Materials • Part A: Ferrous materials • Part C: Welding rods, electrodes and filler metals • ASME Section V Non-destructive Testing • ASME Section VIII DIV. 1 Rules for Construction of Pressure Vessels
ASTM	• ASTM A516 Specification for Pressure Vessel Plates, Carbon Steel for Moderate and Lower Temperature Services. • ASTM A36 Specification for Structural Steel.
AWS	• AWS D1.1 Structural Welding Code –Steel • AWS B2.1 Specification for Welding Procedure and Performance Qualification.

Separator

- Separators shall be designed in accordance with the Local Government and ASME code for Unfired Pressure Vessels, Section VIII, Division1, with al subsequent addenda.
- All such vessels are to be inspected per ASME and Code Stamped.
- Pressure Vessel shall be certified by third party Certified Inspector authorized by EBKTE, licensed by these Regulation checked by and witnessed by the Employer.

FLUID COLLECTION AND REINJECTION SYSTEM

- Hot brine pump

Standard	
ASME	• ASME B73.1 Specification for Horizontal, End Suction Centrifugal Pumps for Chemical Process. • API 610 Centrifugal Pump

- In general, copper or copper alloyed materials will be avoided.
- No copper or copper alloyed materials will be allowed for components coming into contact with geothermal fluids or vapours.

FLUID COLLECTION AND REINJECTION SYSTEM

- Cold condensate pump

Standard	
ASME	• ASME B73.1 Specification for Horizontal, End Suction Centrifugal Pumps for Chemical Process. • API 610 Centrifugal Pump

- In general, copper or copper alloyed materials will be avoided.
- No copper or copper alloyed materials will be allowed for components coming into contact with geothermal fluids or vapours.

FLUID COLLECTION AND REINJECTION SYSTEM

- Pump(general requirement for inspection/maintenance)
  - Pumps shall be designed to minimize the time required for both routine and major maintenance.
  - Equipment shall be equipped with suitable jackscrews, lifting lugs, eyebolts, rails, guide dowels or maintenance procedures to facilitate alignment, disassembly, and re-assembly. Access to any instrumentation shall not require major disassembly.
  - Pumps shall be designed for removal of fluid and components without disturbance of piping or removal of the driver.
  - Adequate clearance for use of socket or box type wrenches shall be provided at the bolting location.
  - Shaft seals and packing shall be accessible for inspection and replacement.

FLUID COLLECTION AND REINJECTION SYSTEM

- Piping

STANDARD	
ASME	• ASMEB31.1 Power Piping • ASME B 16.5 Pipe Flanges and Flanged Fittings • ASME B 16.47Large diameter steel flanges NPS 26 Through NPS 60
API	• API 5L Line Pipe • API 598 Valves Inspection and Test

RECOMMENDED MATERIAL

Materials for the various process and service applications shall be as set out below:

Fluid/Service	Material
Air–Utility	304/316LStainlessSteel
Air–Instrument	304/316LStainlessSteel
Chemicals	316LSS/CPVC
Condensate	316LStainlessSteel
Steam	Carbon steel
Non Condensable Gas(NCG)	316LSS/Fiberglass(FRP)
Oil–Control and Lubricating	304/316LStainlessSteel
Water–Fire Main	HDPE/Cast Iron/Carbon Steel/PVC
Water–Raw	Carbon steel/Stainless Steel/PVC
Water–Circulating and Component Cooling	316LStainlessSteel/FRP

FLUID COLLECTION AND REINJECTION SYSTEM

- Valve

STANDARD	
ASME	• ASME B1.20.1Pipe Threads, General Purpose (Inch) • ASME B16.5 Pipe Flanges & Flanged Fittings • ASME B16.25Butt Welding Ends • ASME B16.34Valves –Flanged, Threaded, and Welding End • ASME B16.47Large Diameters Steel Flanges
ASTM	• ASTM A194Carbon & Alloy Steel Nuts for Bolts for High Pressure or High • Temperature Service or Both • ASTM A105Carbon Steel Forgings for Piping Applications

FLUID COLLECTION AND REINJECTION SYSTEM

- Emergency diesel generator

EQUIPMENT	STANDARD
Diesel engine	• ISO 8528 Reciprocating internal combustion engine driven alternating current generating sets
Generator	• IEC 60034-1 Rotating electrical machines

FLUID COLLECTION AND REINJECTION SYSTEM

- Compressed air system

STANDARD	
API	• API 618 Reciprocating Compressor for Petroleum, Chemical and Gas Industry Services. • API 619 Rotary Type Displacement Compressor for Petroleum, Chemical and Gas Industry Services.

FLUID COLLECTION AND REINJECTION SYSTEM

- Fire firefighting and fire detection system

STANDARD	
NFPA	• NFPA 10 Standard for Portable Fire Extinguishers • NFPA 17 Standard for Dry Chemical Extinguishing Systems • NFPA 70 National Electrical Code • NFPA 72 National Fire Alarm Code

The basic type of fires to be encountered are Classes A, B and C and are defined as follows(as per NFPA):

- CLASS A: Ordinary combustibles such as wood, paper, cloth, etc.
- CLASS B: Flammable liquids
- CLASS C: Electrical equipment

GEOTHERMAL POWER PLANT

- Turbine & auxiliaries
- Condensing & gas extraction system
- Circulating water system
- Auxiliary cooling water system
- Cooling tower
- Generator
- Transformer
- Emergency Diesel Generator

GEOTHERMAL POWER PLANT

- Turbine & auxiliaries

STANDARD		REMARK
ISO	IEC 60045 STEAM TURBINES	
AISI	AISI 316L Stainless Steel	Turbine oil tank, lubricating oil cooler

The American Iron and Steel Institute (AISI)

GEOTHERMAL POWER PLANT

- Condensing & gas extraction system

STANDARD		REMARK
AISI	AISI 316L Stainless Steel	• The condenser, the nozzles,the all internal part and cooler shells • Ejectors body and nozzles • Piping of valves

GEOTHERMAL POWER PLANT

- Circulating water system

STANDARD		REMARK
AISI	AISI 316L Stainless Steel	• Hot water pump impeller, casing, intake bell, riser, discharge bend • Wetted surface of valves

GEOTHERMAL POWER PLANT

- Auxiliary cooling water system

The Auxiliary Cooling Water System transfers heat, directly or indirectly from the thermal cycle. The system is extracts cold water tapping from the line back from the cooling towers basin to the condenser.

GEOTHERMAL POWER PLANT

- Auxiliary cooling water system

The cooling system is supplying cold water for:

- Condensing the steam of the gland ejector and of the gas compression system(first stage gas ejector inter condenser plus liquid ring vacuum pumps separators and in alternative the second stage standby ejector after condenser). Return line is to the condenser.
- Quenching the flashing condensate of the power house blowdown tank.
- Transferring heat from the generator coolers, lube oil coolers and compressed air coolers,
- Providing water make up to the liquid ring vacuum pumps;
- The cooling water flows through the oil coolers and the generator air coolers drawn by the pressure difference between the point where cold water is tapped and the suction pipe of the hot water pumps.

GEOTHERMAL POWER PLANT

- Auxiliary cooling water system

If necessary, circulation of cooling water with the necessary pressure shall be assured by two centrifugal pumps(2x100% duty) to the sprinklers of the inter condenser and after condenser(gas extraction system), to the water make up of the liquid ring vacuum pumps and to the compressed air system. Furthermore the system shall supply the water needed by the blowdown tank, flash vessel and during the start-up of the hot water pumps.

GEOTHERMAL POWER PLANT

- Auxiliary cooling water system

Standard	Remark
AISI 316L Stainless Steel	Equipment, valve, piping

The American Iron and Steel Institute (AISI)

GEOTHERMAL POWER PLANT

- Cooling tower

STANDARD	
CTI	CTI 105 standard

Cooling Tower Institute (CTI)

GEOTHERMAL POWER PLANT

- Generator

Standard	
IEC 6034-1	Rotation electric machines – Rating and performance;
IEC 6034-3	Specific requirement for cylindrical rotor synchronous machines;
IEC 6034-4	Rotating electrical machines – Part 4: Methods for determining synchronous machine quantities from tests;
IEC 6034-5	Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification;
IEC 6034-6	Methods of cooling;
IEC 6034-7	Classification of type of constructions;
IEC 6034-8	Terminal markings and direction of rotation;
IEC 61439-1	Low – voltage switch gear and control gear assemblies;
IEC 60529	Protection degrees (IP code).

IEC(International Electrotechnical Commission)

INSPECTION/MAINTENANCE

Turbine

The problems potentially associated with the turbine are:

- Scaling of the flow control valve and nozzles (primarily in the stator inlet stage);
- Stress corrosion of rotor blades;
- Erosion of turbine (rotor and stator) blades and turbine housing.

INSPECTION/MAINTENANCE

Turbine

- The rate and seriousness of scaling in the turbine are directly related to the steam cleanliness, i.e. the quantity and characteristics of separator “carry-over“. Thus the operation and efficiency of the separator are of great importance to trouble free turbine operation.
- Prolonged operation of the power plant off-design point also plays a significant role.

INSPECTION/MAINTENANCE

Turbine

- Most of the scaling takes place in the flow control valve and the first stator nozzle row.
- The effect of this scaling is:
  - A significant drop-off in generating capacity as sufficient steam cannot enter the turbine, and;
  - Sluggish response to load demand variations.

INSPECTION/MAINTENANCE

Turbine

- This situation is easily monitored, since the build-up of scales causes the pressure in the steam chest between the control valve and the inlet nozzles to increase over time.
- Significant turbine and control valve scaling is avoided by the adoption of careful flasher/separator plant operating practices that minimize “carry-over“, and moreover selecting a high efficiency mist eliminator by the power plant.

INSPECTION/MAINTENANCE

Turbine

- Significant scaling in turbine and control valve requires scheduled maintenance stops for inspection and cleaning, every second or third year.
- Another means of reducing turbine cleaning frequency, is to inject condensate into the inlet steam during plant operation and run the turbine at say 10% wetness for a short period. This washes away nozzle scaling, in particular. This cleaning technique if properly applied has been found to reduce the frequency of major turbine overhaul.

INSPECTION/MAINTENANCE

Condenser

- The steam-water mixture emitted from the turbine at outlet contains a significant amount of non condensable gases comprising mainly CO_2 (which is usually 95–98% of the total gas content), CH_4 and H_2S, and is thus highly acidic.
- Since most high-temperature geothermal resources are located in arid or semi-arid areas far removed from significant freshwater (rivers, lakes) sources, the condenser cooling choices are mostly limited to either atmospheric cooling towers or forced ventilation ones.

INSPECTION/MAINTENANCE

Condenser

- The application of evaporative cooling of the condensate results in the condensate containing dissolved oxygen in addition to the non-condensable gases, which make the condenser fluid highly corrosive and require the condenser to be clad on the inside with stainless steel;

INSPECTION/MAINTENANCE

Condenser

- Condensate pumps to be made of stainless steel, and all condensate pipelines either of stainless steel or glass reinforced plastic.
- Addition of caustic soda is required to adjust the pH in the cooling tower circuit.
- Make-up water and blow-down is also used to avoid accumulation of salts in the water caused by evaporation.

INSPECTION/MAINTENANCE

Condenser

- A problem sometimes encountered within the condenser is the deposition of almost pure Sulphur on walls and nozzles within the condenser.
- This scale deposition must be periodically cleaned by high pressure water spraying etc.

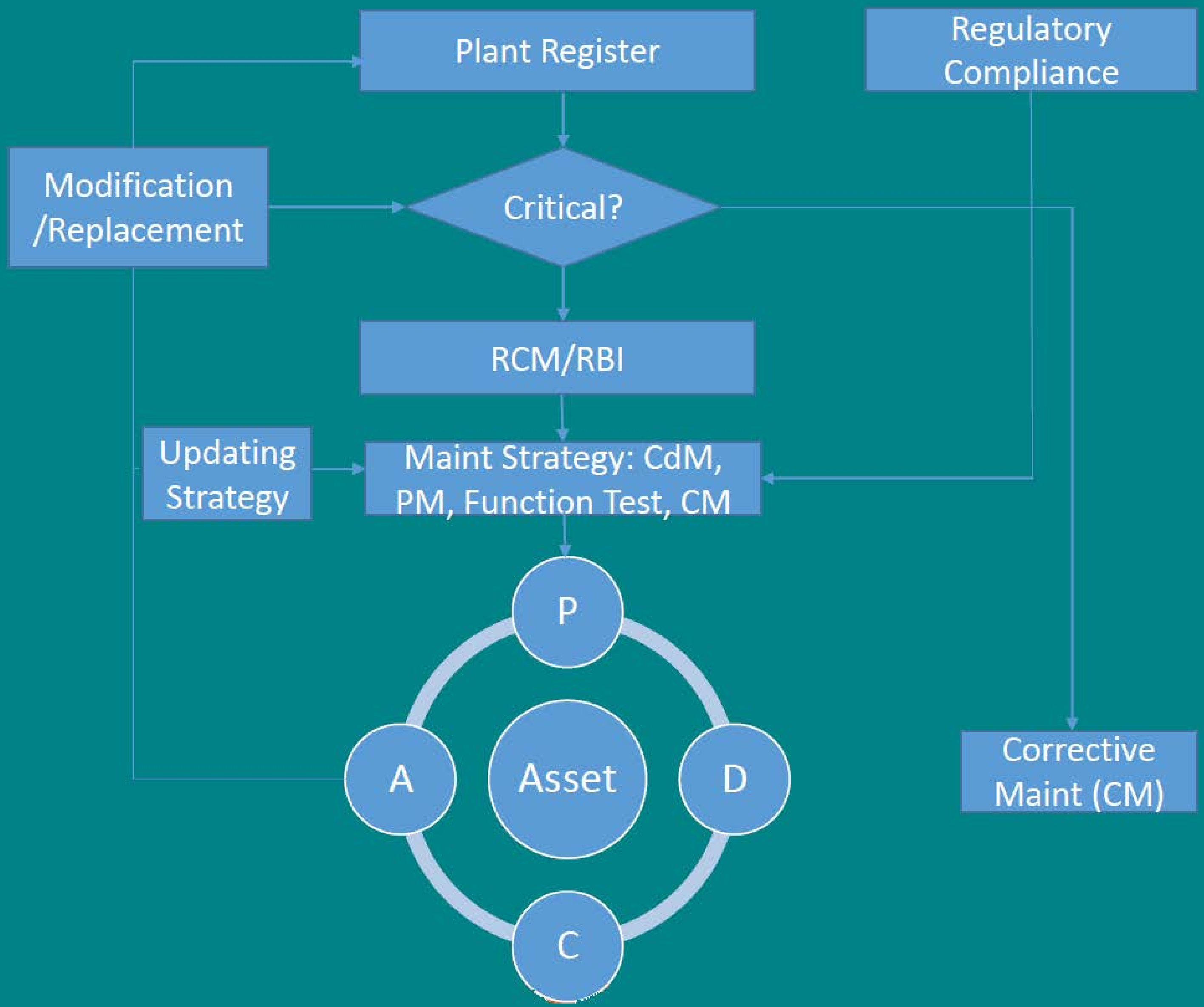
Source : UNU GTP

ASSET INTEGRITY MANAGEMENT IN GEOTHERMAL POWER PLANT

Overview

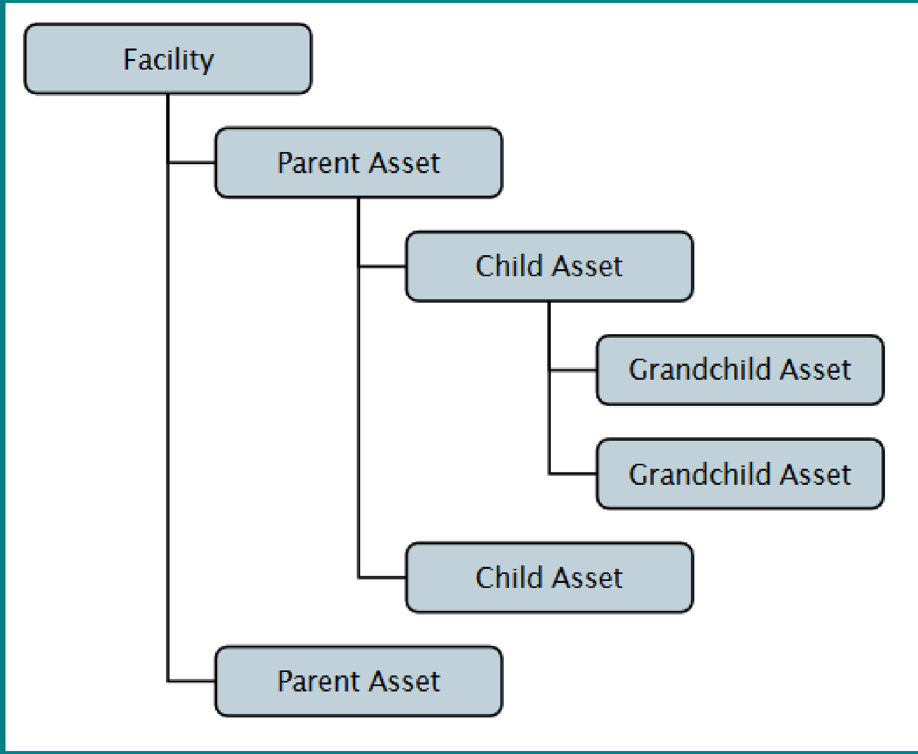
- Asset Integrity Management Concept
- Asset Registration
- Criticality Assessment
- Legal/Regulation Compliance
- Developing Maintenance Program
- Planning & Scheduling

ASSET INTEGRITY MANAGEMENT CONCEPT



ASSET REGISTRATION

- Defined as a systematic recording/register of all assets owned by the organization.
- Uses a specific plant numbering system to which attribute information can be linked.
- Could be hierarchical based until the lowest level of asset could be maintained.
- Consist of the overall data of the assets such as:
  - Functional Location
  - Equipment Data
    - Tag Number
    - Equipment Description
    - Planning Plant
    - Drawing Number
    - Manufacturer
    - Model Number
    - Part Number
    - Serial Number
    - Size/Dimension
  - Bill of Material



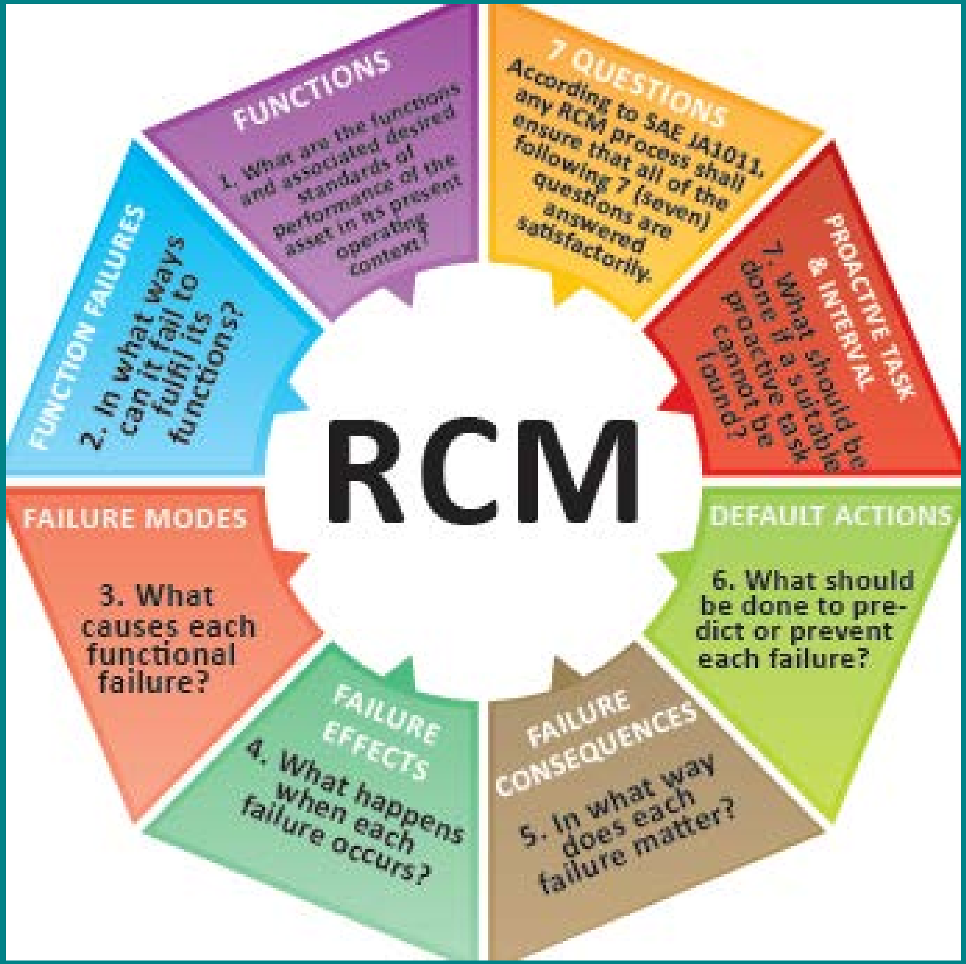
REGULATORY COMPLIANCE

- ✓SKPI (Facility Worthiness Certification)
- ✓SKPP (Individual Equipment Certification)
  - ✓Pressure Vessel, Heat Exchanger, Cooler
  - ✓Pressure Safety Valve (PSV)
  - ✓Lifting equipment
  - ✓Electrical equipment (Power Generator Unit, Power Transformer Unit, Switchgear, and Motor Control Centre Unit)
  - ✓Rotating Equipment (Pump & Compressor Unit
  - ✓Pipeline
  - ✓Tank

DEVELOPING MAINTENANCE PROGRAM -RCM

RCM: A process which is used to define what should be done to ensure any physical assets could continuously operate as user needed in their operating context(Moubray, 1997)

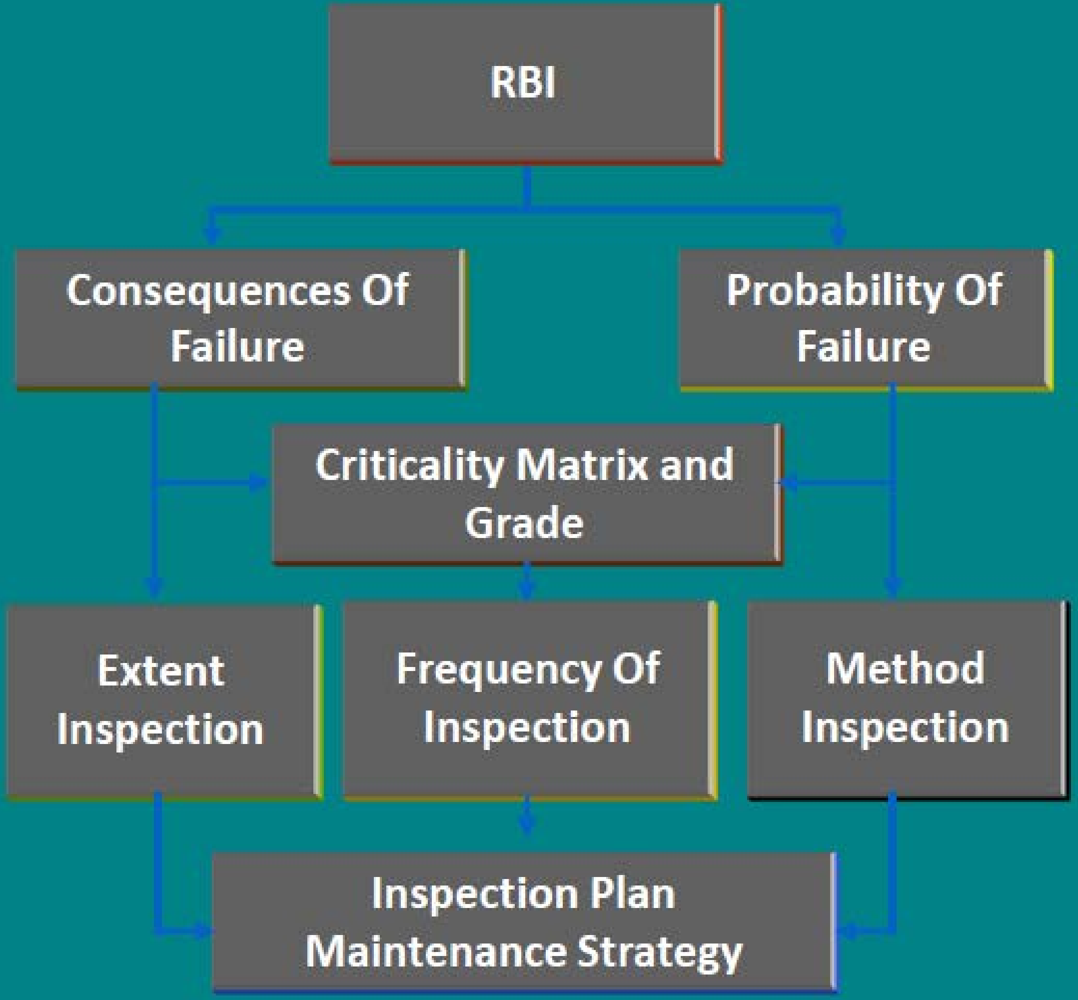
In Geothermal Application, RCM Analysis is performed for defining maintenance program for rotating equipment such as Turbine, Generator, Pump, etc.



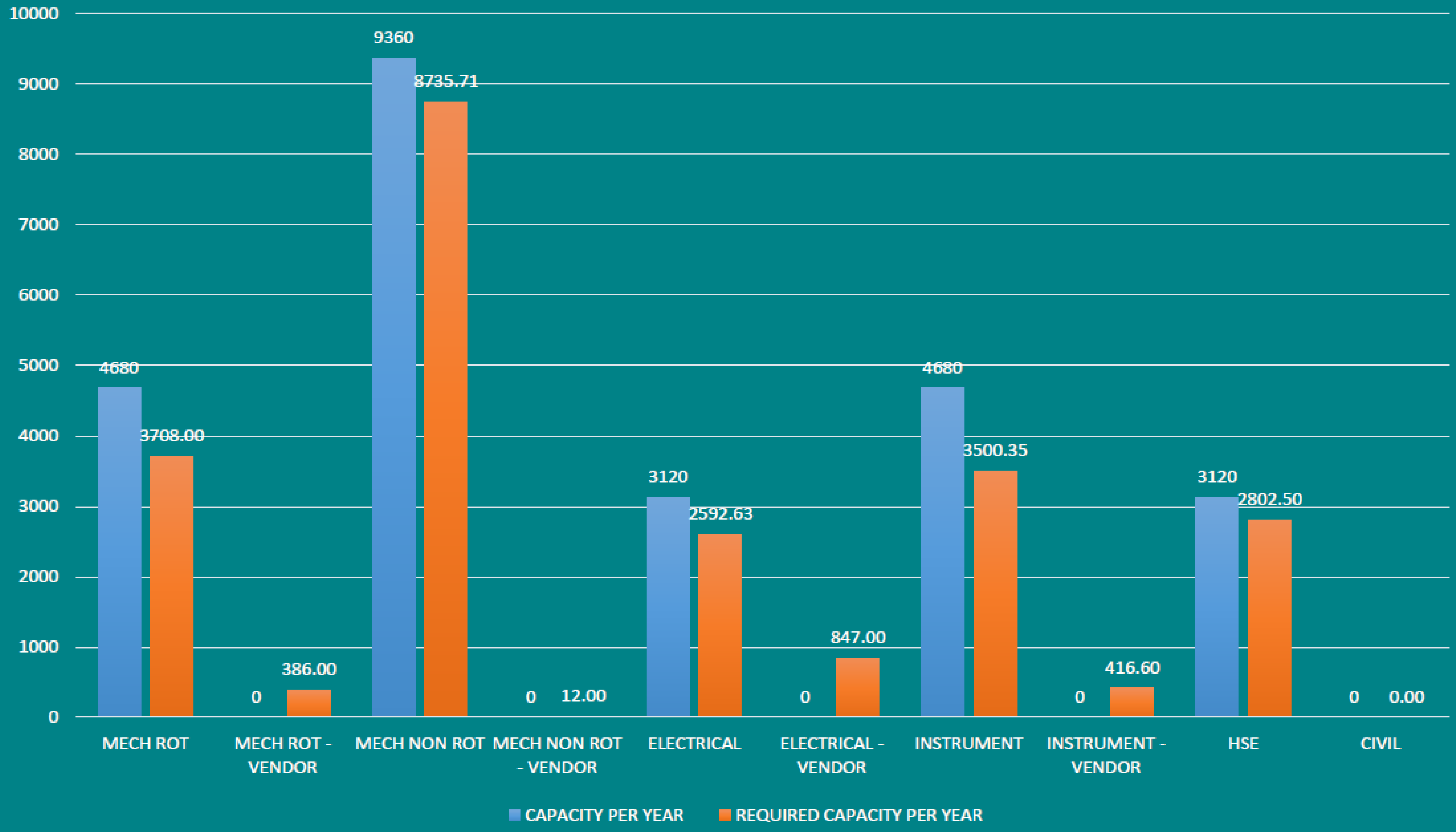
DEVELOPING MAINTENANCE PROGRAM -RBI

RBI:A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to damage mechanisms. These risks are managed primarily through equipment inspection(API581, 2016)

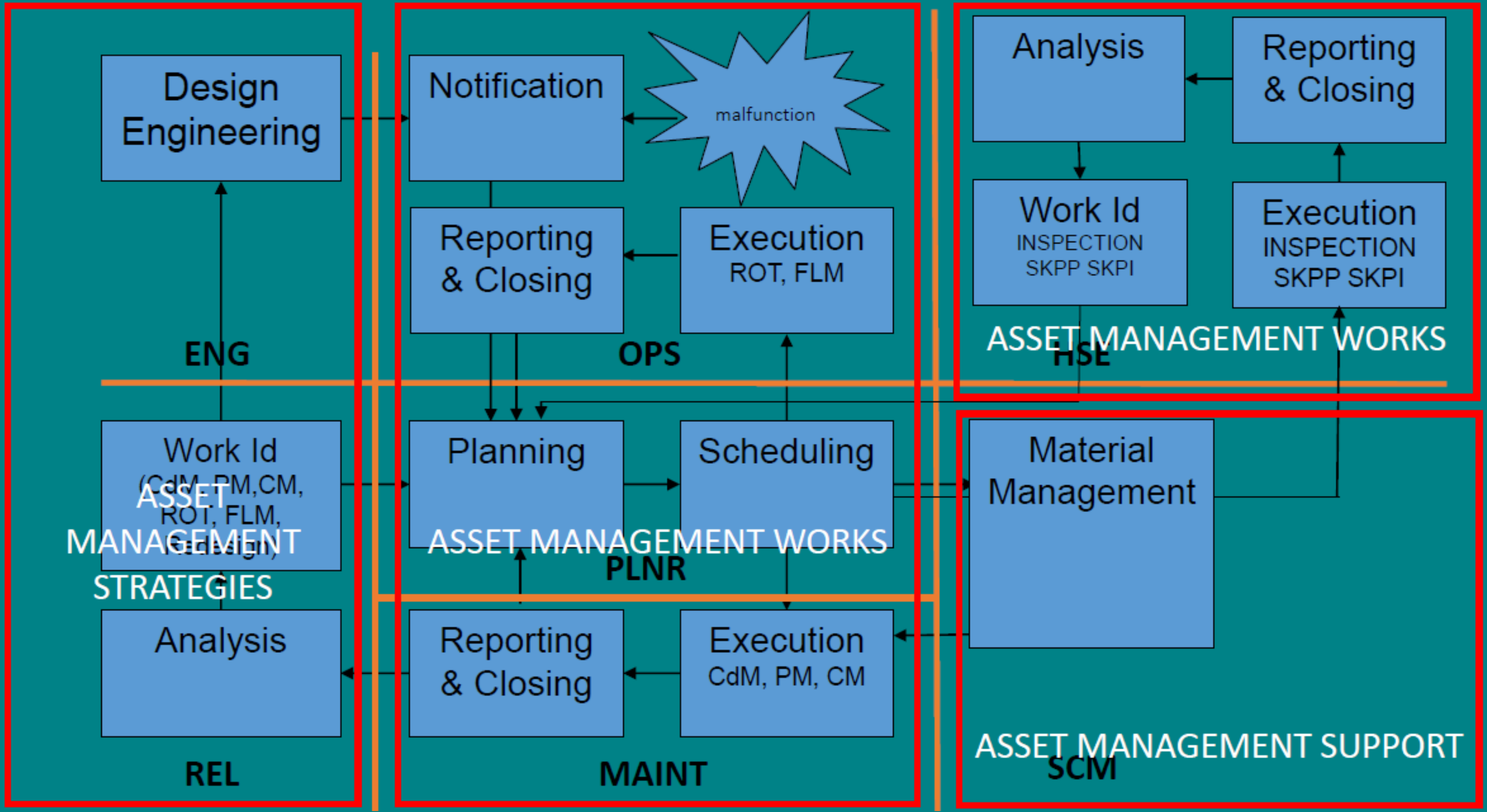
In Geothermal Application, RBI Analysis is performed for defining maintenance program for static equipment such as pipeline, tank & vessel.



PLANNING & SCHEDULING



Asset Management in Overall PM Process



THANK YOU