DESIGN OF A HIGH EFFICIENCY WASTE TO ENERGY PLANT IN BRAZIL CONSUMING A LIMITED AMOUNT OF NATURAL GAS

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WasteEng 14

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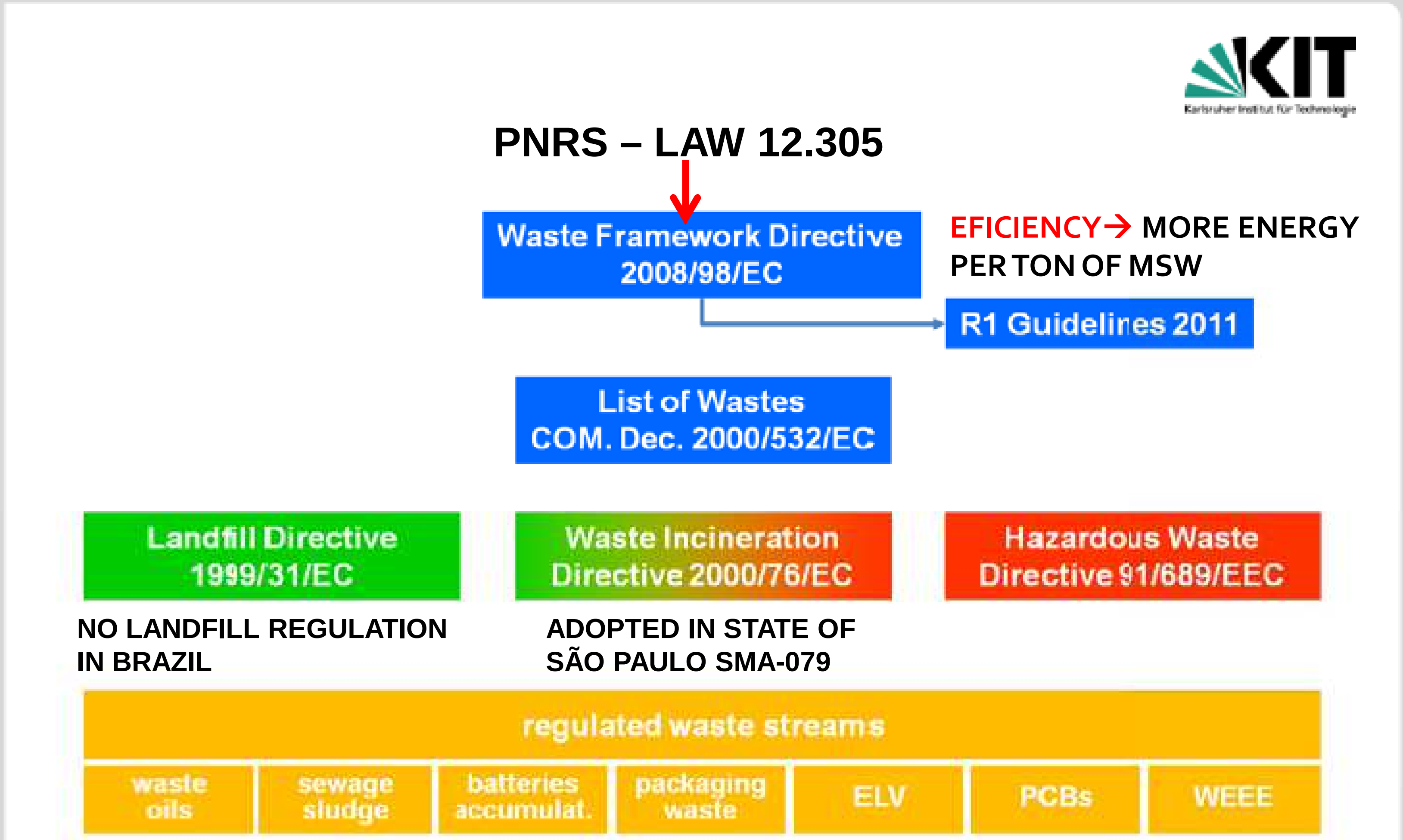
EU DIRECTIVES x MSW BRAZILIAN POLICE (PNRS)



CONSEQUENCE → LANDFILLS VERY CHEAP (POOR QUALITY)

WTE →DIFFICULT ECONOMIC FEASIBILITY → LOW TIPPING FEES BUT ELECTRICITY PRICES TEND TO GO UP WITH LACK OF RAIN

HIGHER EFFICIENCY MAY HELP IMPROVING

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CONVENTIONAL WTE PLANTS (40 bar / 400ºC)

Electrical Efficiency of Power Plants

Depends on fuel quality:

• Natural Gas	55 %
• Oil	50 %
• Coal	45 %
• Lignite	40 %
• Biomass	35 %
• Waste	15…22 %….30%

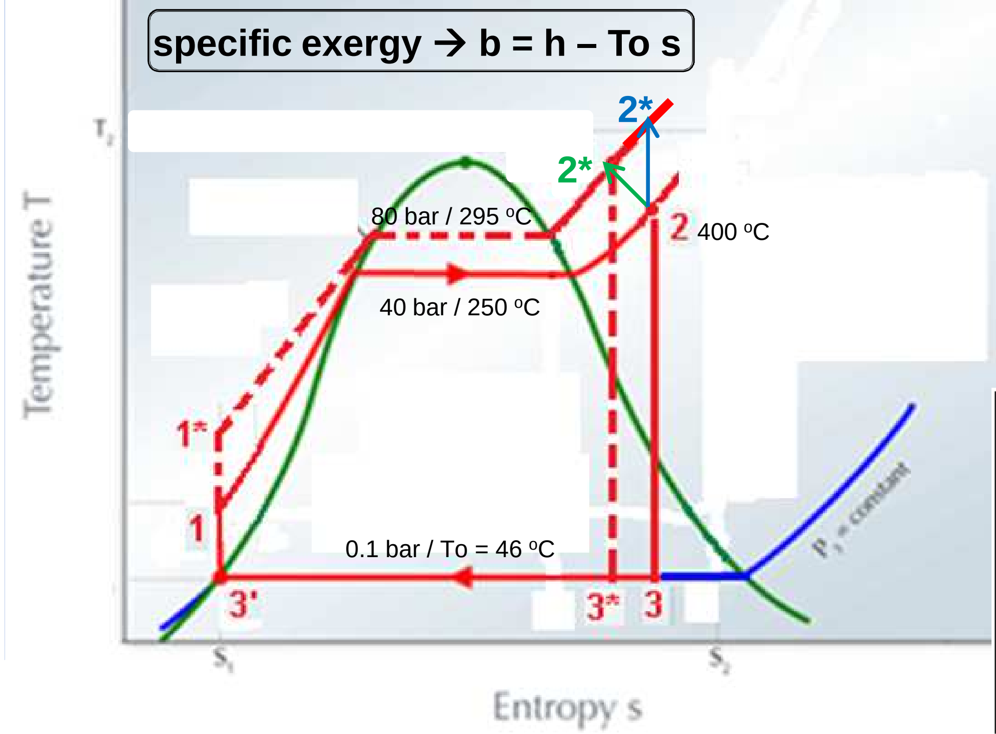
Current Average

Current: State-of-the-Art

New: Best Available Technology

ISENTROPIC TURBINE RANKINE CYCLE

specific exergy → b = h – To s



Q_{in}= 1000 KJ/s

A	P -bar	T-°C	h-KJ/kg	s-KJ/(kg.°K)	b-KJ/kg	mv.b-KJ/s	X
1	40	45,95	195,86	0,6493			
2	40	400,00	3213,40	6,7688	1055,39	**349,75**	
3	0,1	45,82	2143,76	6,7688			0,8160
3'	0,1	45,82	191,83	0,6493			
mv	**0,331**	kg/s					
Qout	646,86	KJ/s					
Ef=	**35,31%**						

B	P -bar	T-°C	h-KJ/kg	s-KJ/(kg.°K)	b-KJ/kg	mv.b-KJ/s	X
1*	80	46,08	199,89	0,6493			
2*	80	427,58	3213,40	6,4728	1149,77	**381,54**	
3*	0,1	45,82	2049,34	6,4728			0,7766
3'	0,1	45,82	191,83	0,6493			
mv	**0,332**	kg/s					
Qout	616,39	KJ/s	**ISENTHALPIC --> HIGH MOISTURE ST EXIT**				
Ef=	**38,36%**						

C	P -bar	T-°C	h-KJ/kg	s-KJ/(kg.°K)	b-KJ/kg	mv.b-KJ/s	X
1*	80	46,08	199,89	0,6493			
2*	80	514,05	3433,21	6,7688	1275,21	**394,40**	
3*	0,1	45,82	2143,76	6,7688			0,8160
3'	0,1	45,82	191,83	0,6493			
mv	**0,309**	kg/s					
Qout	603,69	KJ/s	**ISENTROPIC --> SH TEMPERATURE TOO HIGH**				
Ef=	**39,63%**						

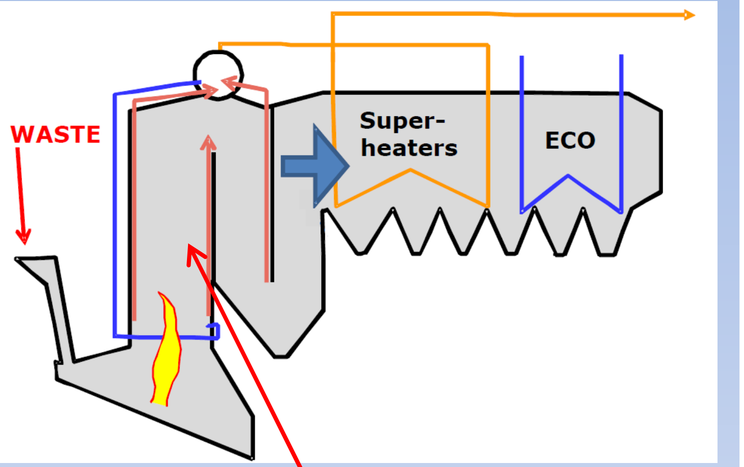
D	P -bar	T-°C	h-KJ/kg	s-KJ/(kg.°K)	b-KJ/kg	mv.b-KJ/s	X
1*	69	46,04519	198,7842	0,6493			
2*	69	464,71	3325,352	6,6913	1192,07	**381,27**	
3*	0,1	45,81718	2119,031	6,6913			0,8057
3'	0,1	45,81718	191,8336	0,6493			
mv*	**0,320**	kg/s					
Qout	616,39	KJ/s	**SAME EFICIENCY = SAME EXERGY**				
Ef=	**38,36%**						

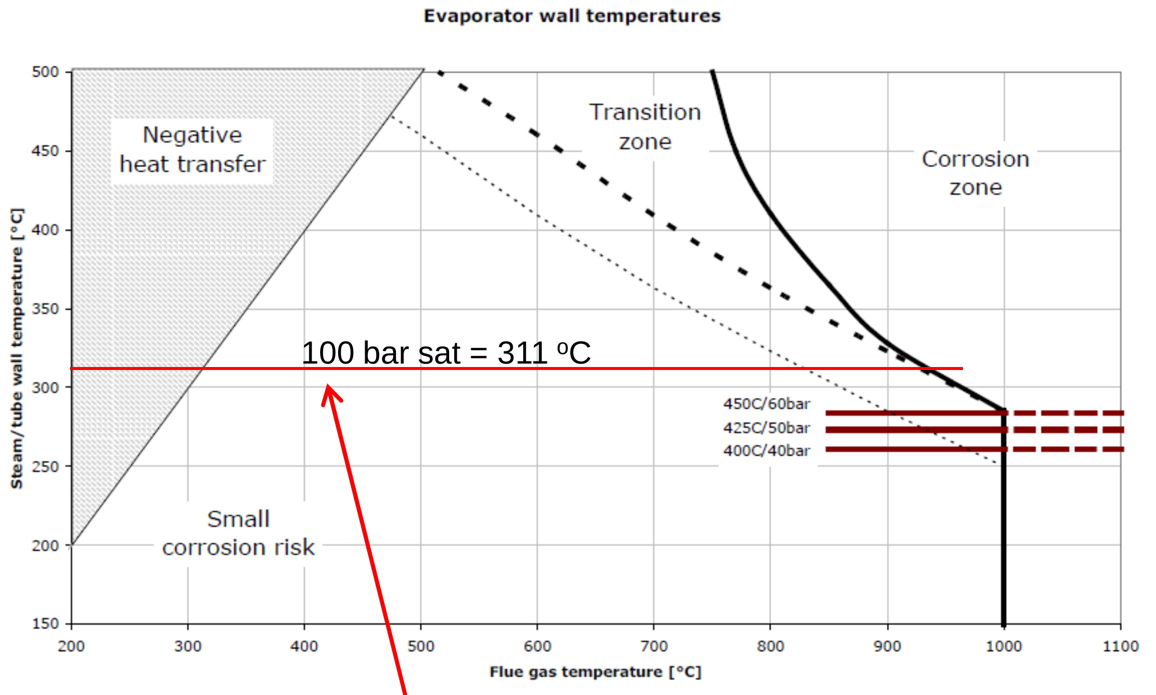
EXERGY FOLLOWS EFFICIENCY

THE OPTIMUM SOLUTION SHOULD CONSIDER THE HIGHEST POSSIBLE EXERGY AVOIDING PRESSURE (COST) AND TEMPERATURE (COST/CORROSION) TOO HIGH.

THIS WORK PRESENTS A USEFUL TOOL AIMING THE BEST OVERALL SOLUTION. HIGH EFFICIENCY AND LOW COST.

PRESSURE/TEMPERATURE INFLUENCE ON BOILER CORROSION (KAMUK)





CORROSION IN EVAPORATOR CIRCUIT MAY OCCUR DUE TO SATURATION TEMPERATURE INCREASE WITH PRESSURE – CAN BE WELL CONTROLLED WITH INCONEL CLADDING OF WATERWALL TUBES.

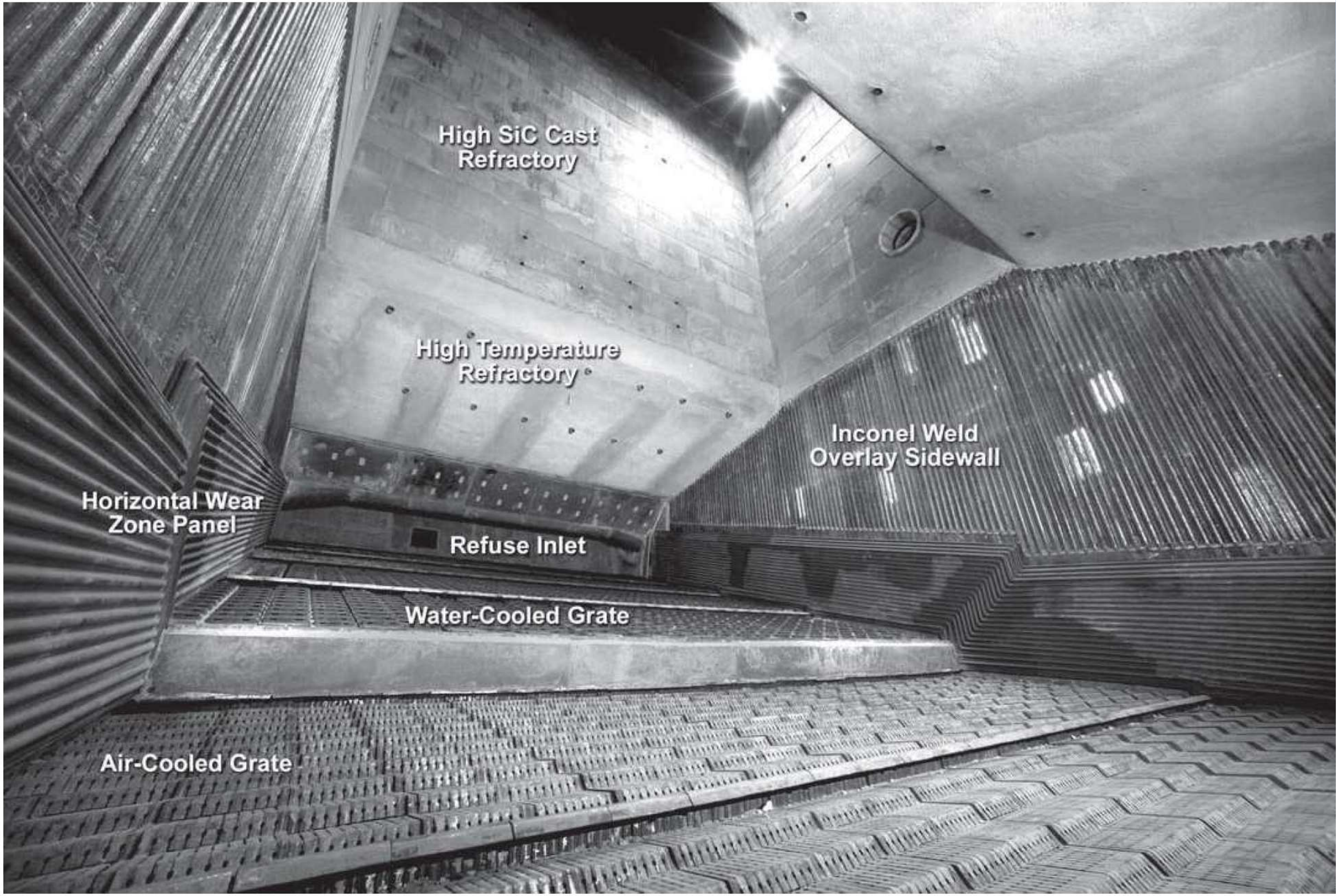
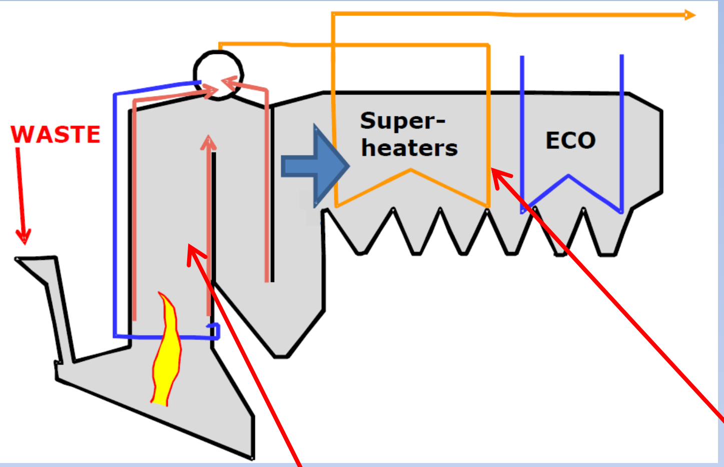
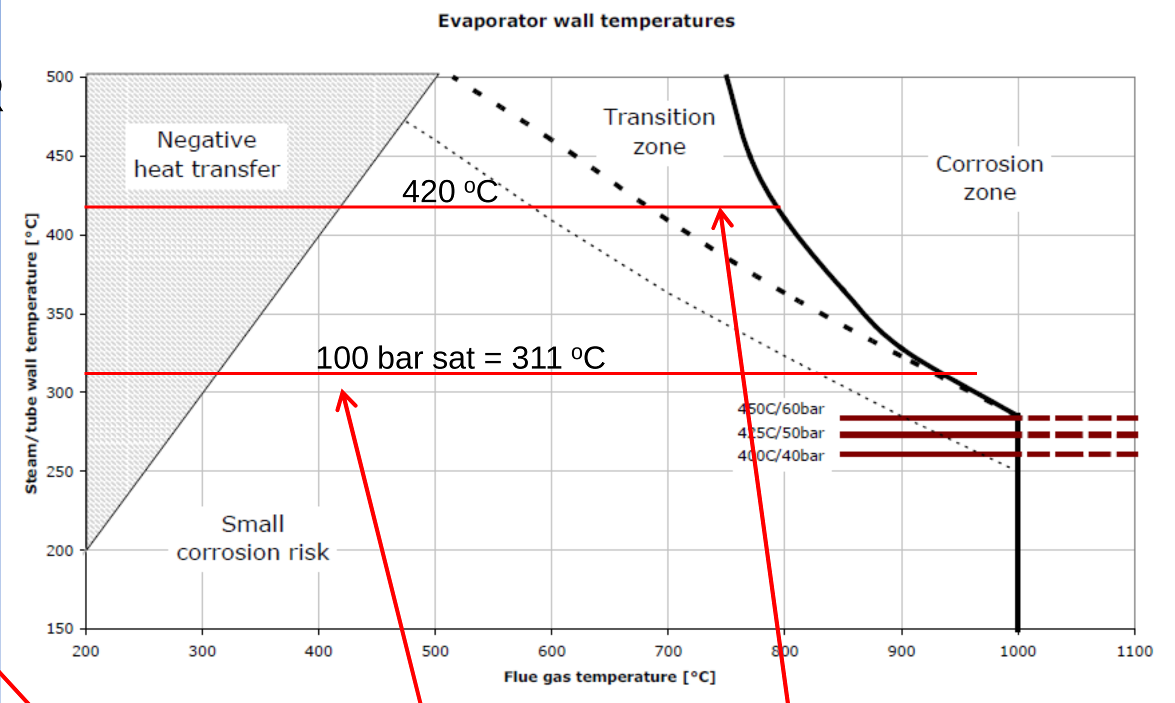


Fig. 7 Corrosion protection and design of a 26 t/h mass-fired unit.

PRESSURE/TEMPERATURE INFLUENCE ON BOILER CORROSION (KAMUK)





CORROSION IN EVAPORATOR CIRCUIT MAY OCCUR DUE TO SATURATION TEMPERATURE INCREASE WITH PRESSURE – CAN BE WELL CONTROLLED WITH INCONEL CLADDING OF WATERWALL TUBES.

CORROSION IN SUPERHEATERS MORE DIFFICULT TO CONTROL. EVEN EXPENSIVE INCONEL TUBES MUST BE REPLACED.

SOLUTIONS WITH MEDIUM PRESSURES < 90 bar AND LOWER TEMPERATURES < 420 ºC IN MSW BOILER ARE BETTER → EXTERNAL SUPERHEATING ~ 500 ºC WITH NATURAL GAS → HYBRID or DUAL FUEL CYCLES

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HYBRID or DUAL FUEL CYCLES CAN HAVE SEVERAL DIFFERENT CONFIGURATION. VERY OFTEN COMPRISE A GAS TOPPING CYCLE AND A STEAM BOTTOMING CYCLE AS SHOWN (PETROV).

GAS TURBINE/STEAM TURBINE

practice and can be employed for purposes like increasing power output from the BC for meeting peak-loads, offsetting the GT loss of power at high ambient temperatures, improving part-load efficiency, or simply achieving higher steam superheat/reheat temperatures, higher flexibility in delivering varying amounts of process steam and possibility to run as a pure steam cycle during GT outage.

GT PRESENT HIGHER TEMPERATURE AND HIGHER O2 IN EXHAUST GASES THAN GAS ENGINES

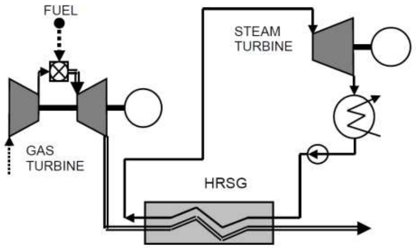


Fig. 1.4: Simplified chart of a straightforward (unfired) GTCC.

DUE TO LOWER TEMPERATURE GAS ENGINES EXHAUST CAN ONLY BE USED AS PARTIAL BOILER COMBUSTION AIR OR FEEDWATER PREHEATING

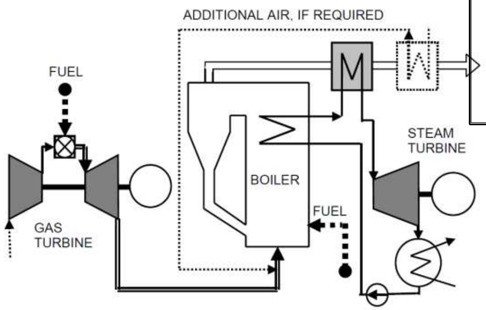


Fig. 1.5: Simplified chart of a fully-fired (windbox) HCC.

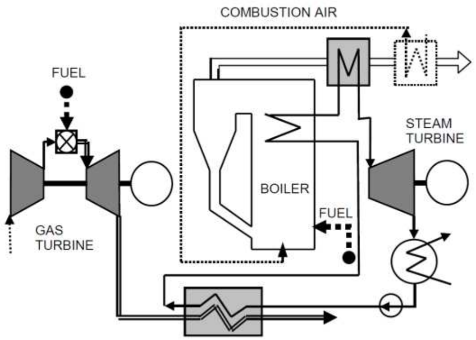


Fig. 1.6: Simplified chart of a parallel-powered HCC with feedwater preheating.

GAS ENGINE/STEAM TURBINE

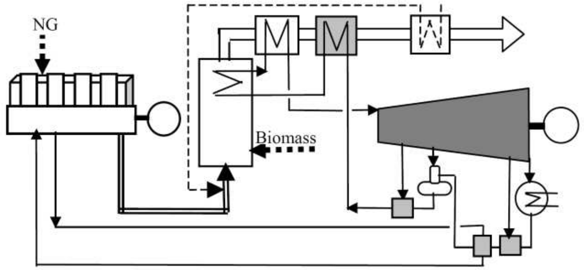


Fig. 1: Simplified schematic of the fully-fired (FF) hybrid combined cycle (hot-windbox type). The engine exhaust gases are directly fed to the biomass-fired boiler and used as combustion air.

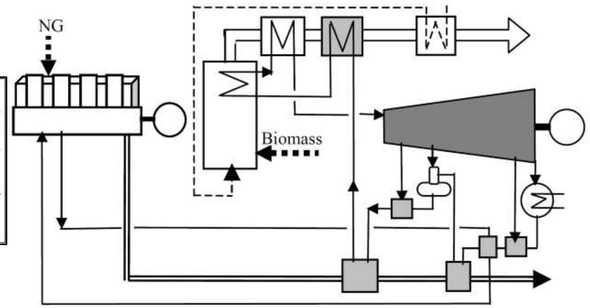


Fig. 2: Simplified schematic of a parallel-powered hybrid cycle with feedwater preheating by engine exhaust (PP-FP).

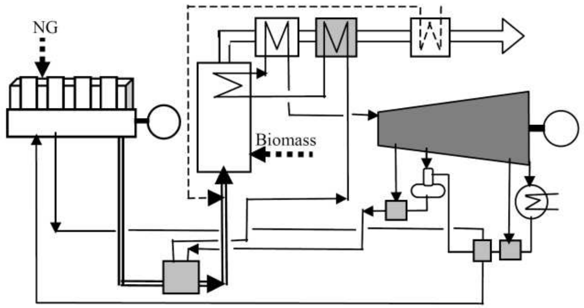
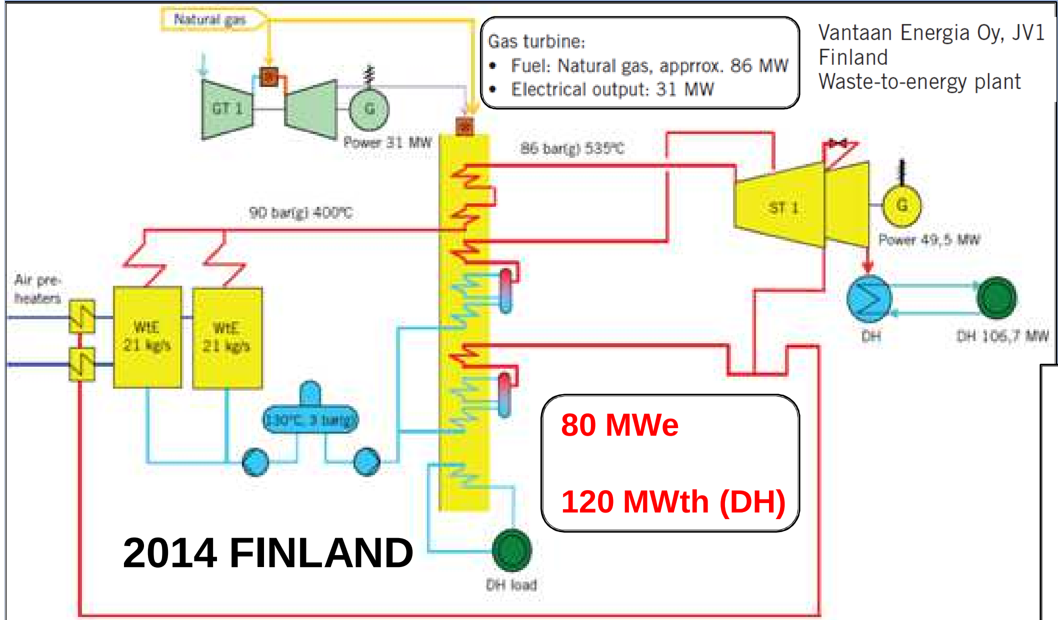
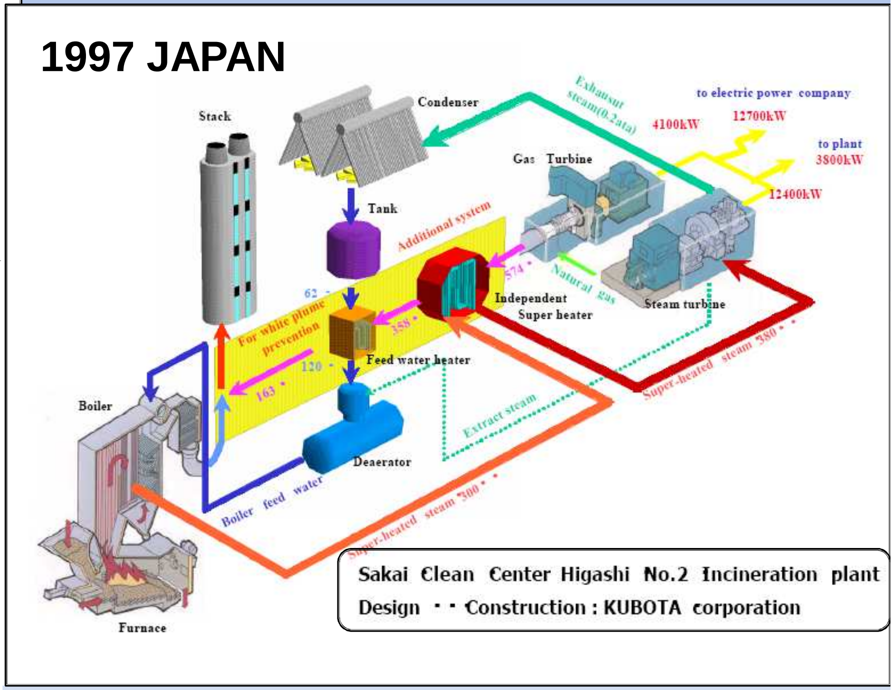
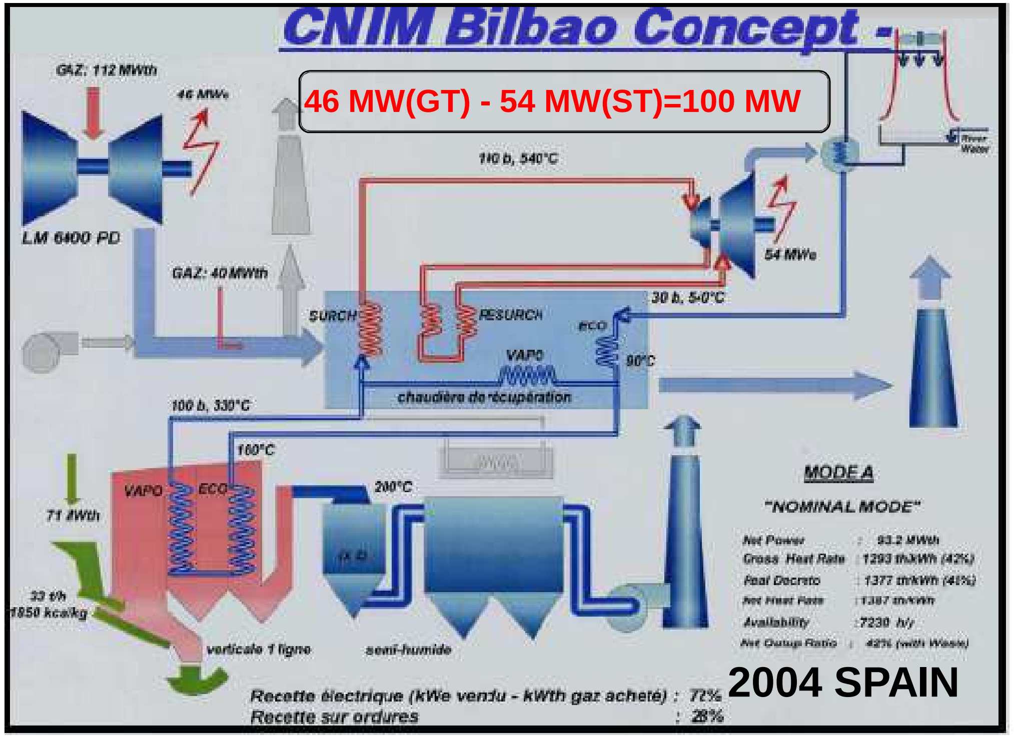


Fig. 3: Simplified schematic of a cold-windbox (mixed parallel-powered/fully-fired) hybrid combined cycle with feedwater preheating by engine exhaust plus using engine exhaust as combustion air in the biomass boiler (FF-PPFP).

HYBRID CYCLES HAVE BEEN USED IN SEVERAL WTE PLANTS

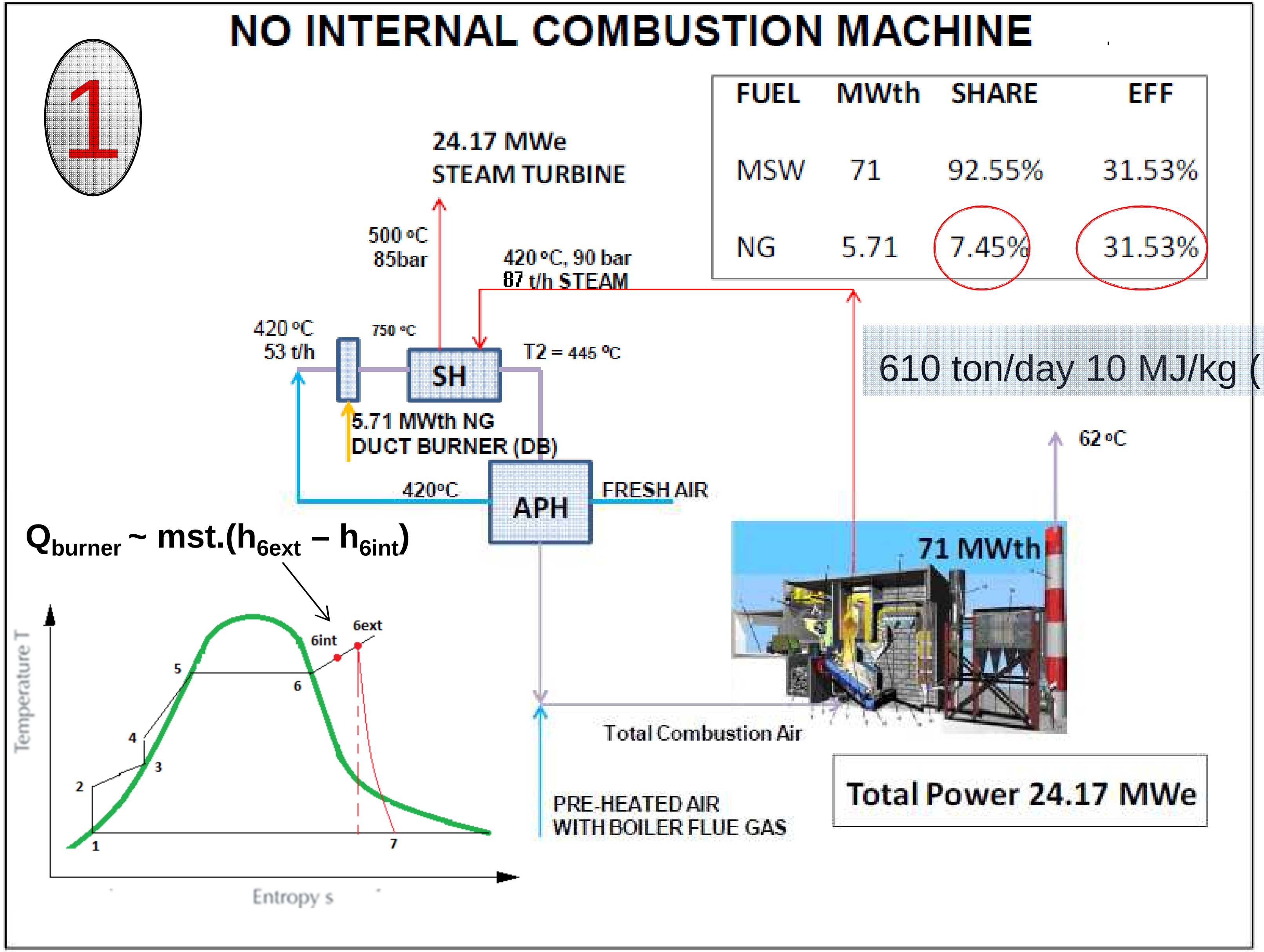






IN ALL THESE PLANTS THE NG SHARE IS VERY HIGH > 35%. IN BILBAO IS 78%

THIS PAPER PROPOSES 3 DIFFERENT CONFIGURATIONS



FUEL	MWth	SHARE	EFF
MSW	71	92.55%	31.53%
NG	5.71	7.45%	31.53%

Figure 4 – OCC Scheme without Internal Combustion Machine

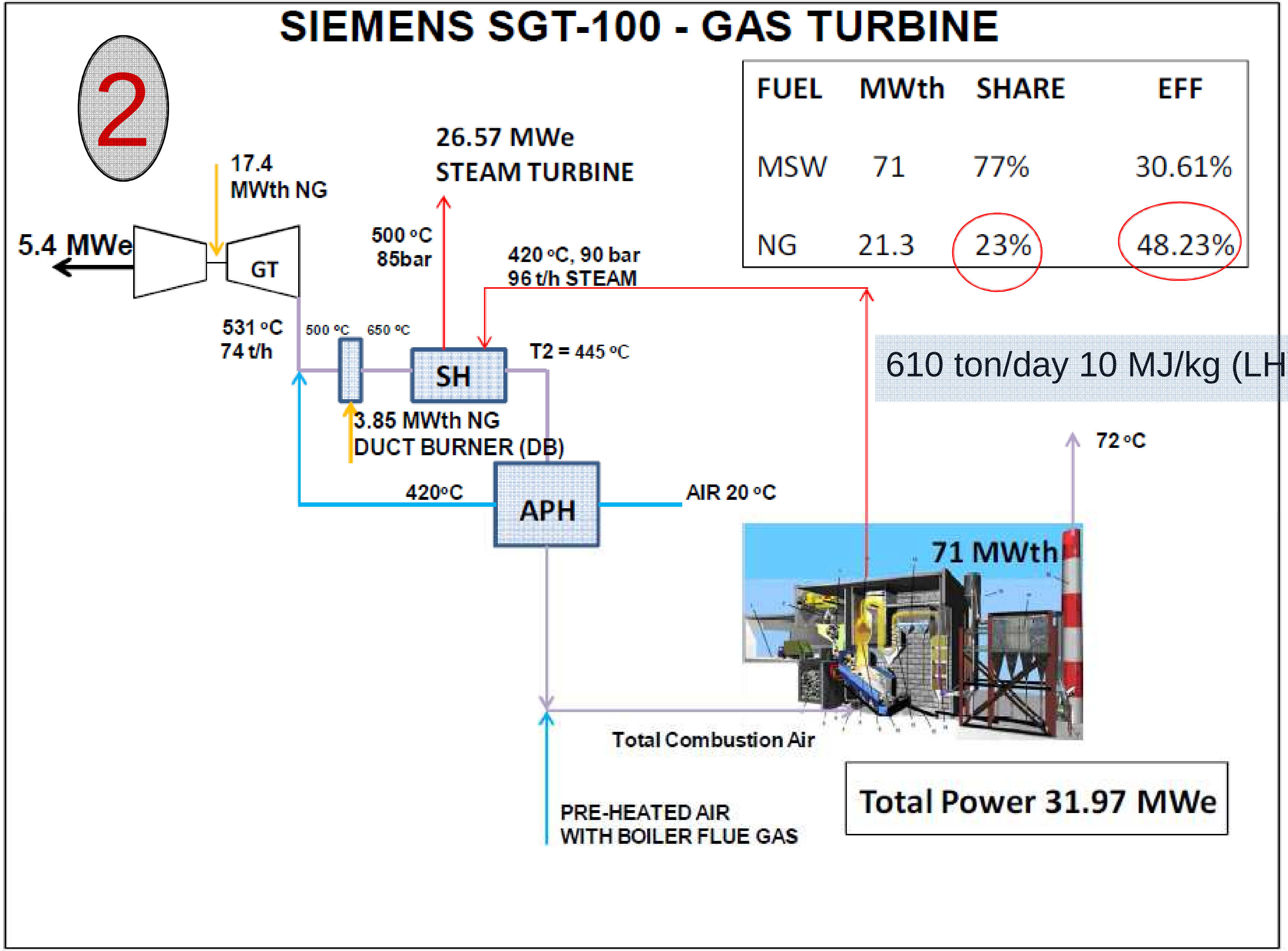


Figure 2 – OCC Scheme Using a Small Gas Turbine

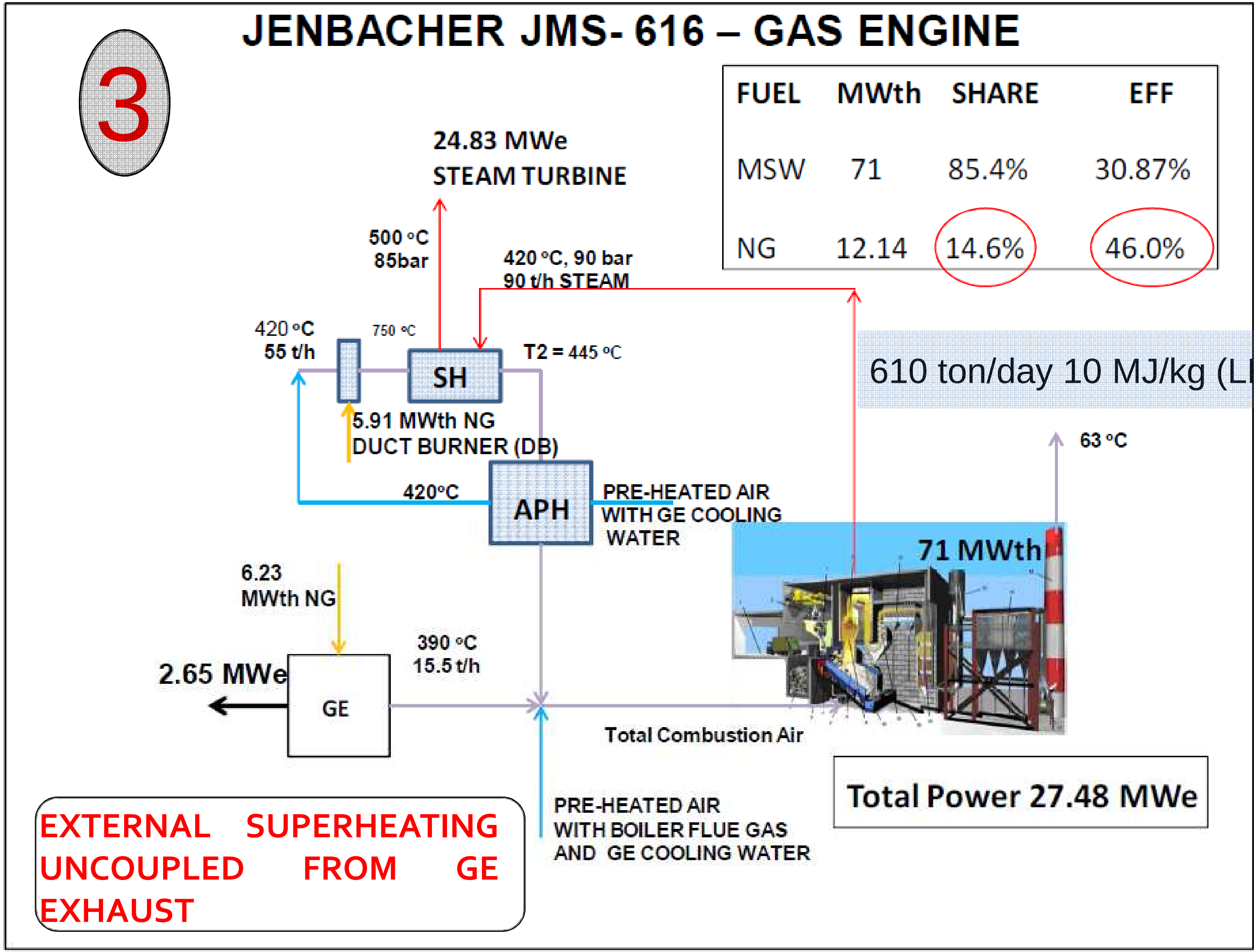


Figure 3 – OCC Scheme Using a Small Gas Engine

EFFICIENCY CONSIDERATIONS

KOROBITSYN

$$\eta_{MSW} = \frac{P_{TOTAL} - F_{NG}.\eta_{CC}}{F_{MSW}}$$

η_{CC} ⟹ **STANDALONE CC NG EFFICIENCY = 52%**

THIS IS OK FOR LARGE GT COMBINED CYCLE PLANTS

NOT ADEQUATE FOR VERY SMALL GT or GE BASED POWER PLANTS

CURRENT WORK

STEAM TURBINE OUTPUT

$$\eta_{MSW} = \frac{W_{ST}}{F_{MSW} + F_{NGT}(1 - \eta_{GT}) + F_{NGB}}$$

TOTAL ENERGY INPUT TO STEAM CYCLE

TOTAL POWER PRODUCED BY NG

$$\eta_{NG} = \frac{W_{GT} + (F_{NG} - W_{GT}).\eta_{MSW}}{F_{NG}}$$

TOTAL NG INPUT

P_{TOTAL} total electric energy produced by the plant, MWe
W_{ST} total electric energy produced by steam turbine, MWe
W_{GT} total electric energy produced by gas turbine, MWe
F_{MSW} thermal energy from MSW, MWth
F_{NGT} thermal energy from natural gas consumed by gas turbine, MWth
F_{NGB} thermal energy from natural gas consumed by gas burner, MWth
$F_{NG} = (F_{NGT} + F_{NGB})$ total thermal energy from natural gas, MWth
η_{GT} open cycle gas turbine efficiency

BOTH FORMULAS GIVE THE SAME RESULTS WHEN THE GT INCREASES IN SIZE

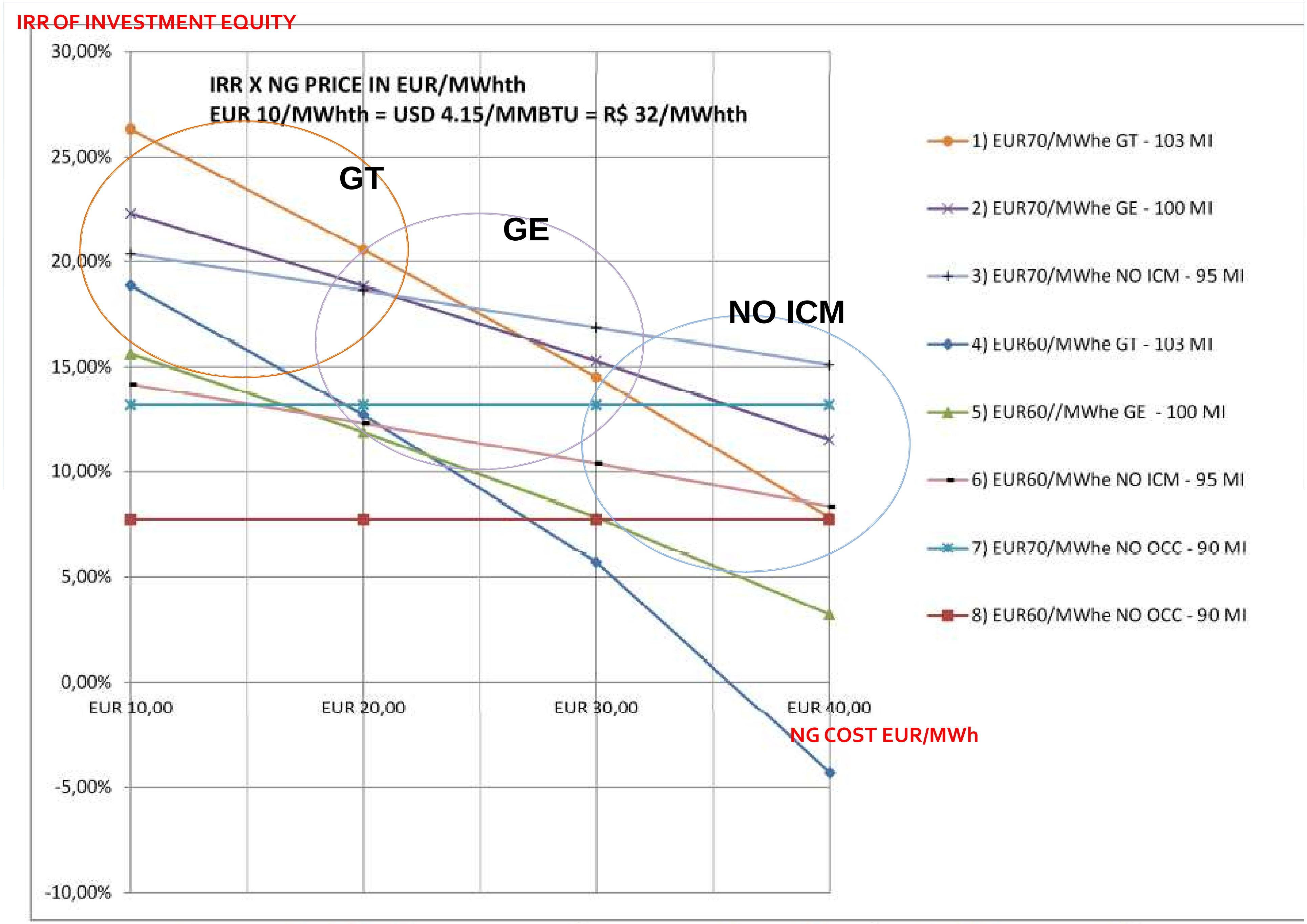


Figure 5 –IRR Comparison between GE, GT and no ICM OCC Solutions

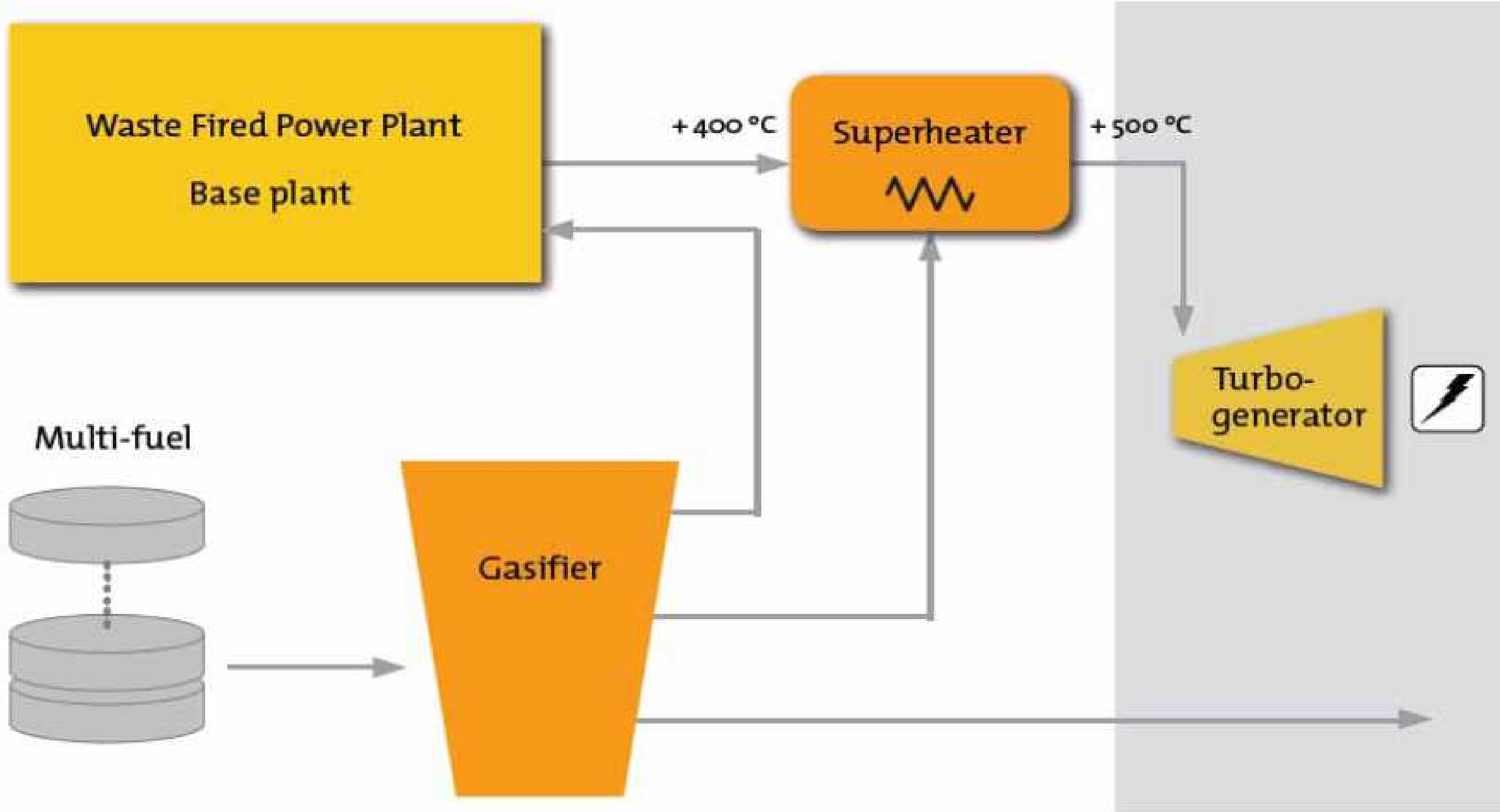
Babcock & Wilcox Vølund
Generating Powerful Solutions™

The Waste Fired Power Plant Gärstad, Sweden

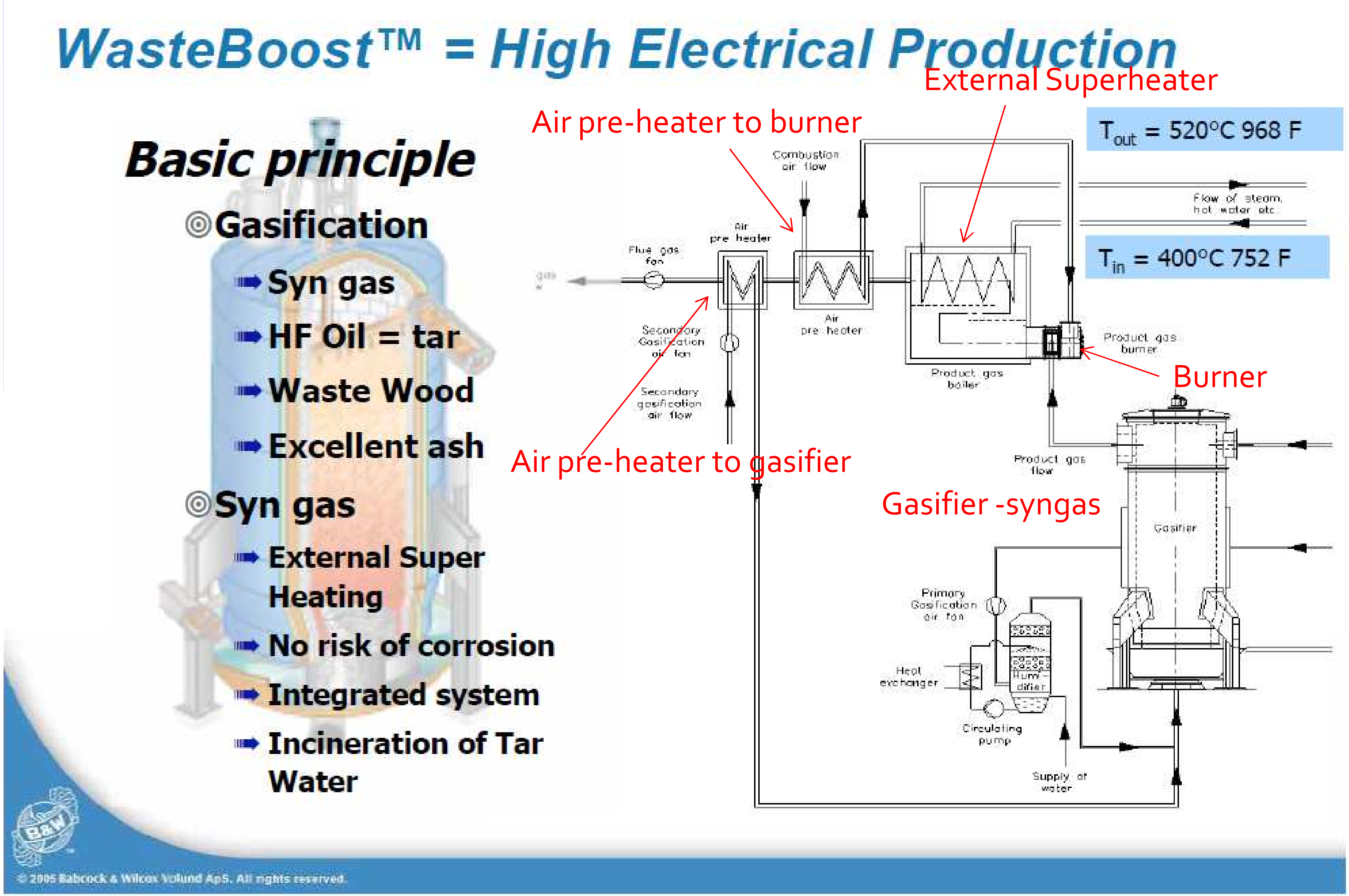
WasteBoost™
Superheating Supplied by Gasification

Babcock & Wilcox Vølund
Generating Powerful Solutions™

WasteBoost™ - superheating of the steam parameters with a VølundSystems™ biomass gasifier.



EXTERNAL SUPERHEATING USING SYNGAS (NO Cl)



LOWEST POSSIBLE NG CONSUMPTION, USE AMSTERDAM REHEAT SCHEME WITH DRUM EXTRACTION STEAM

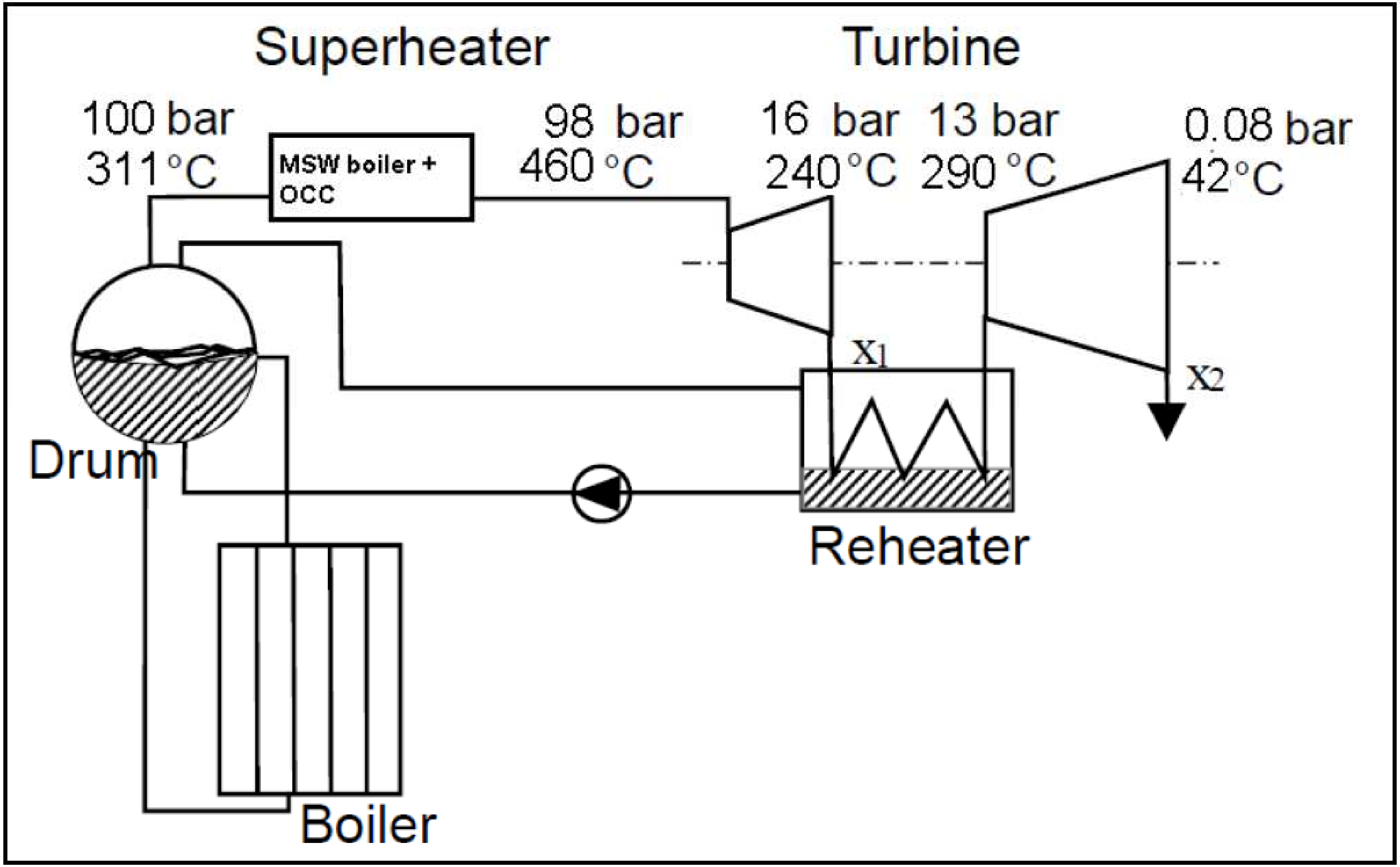
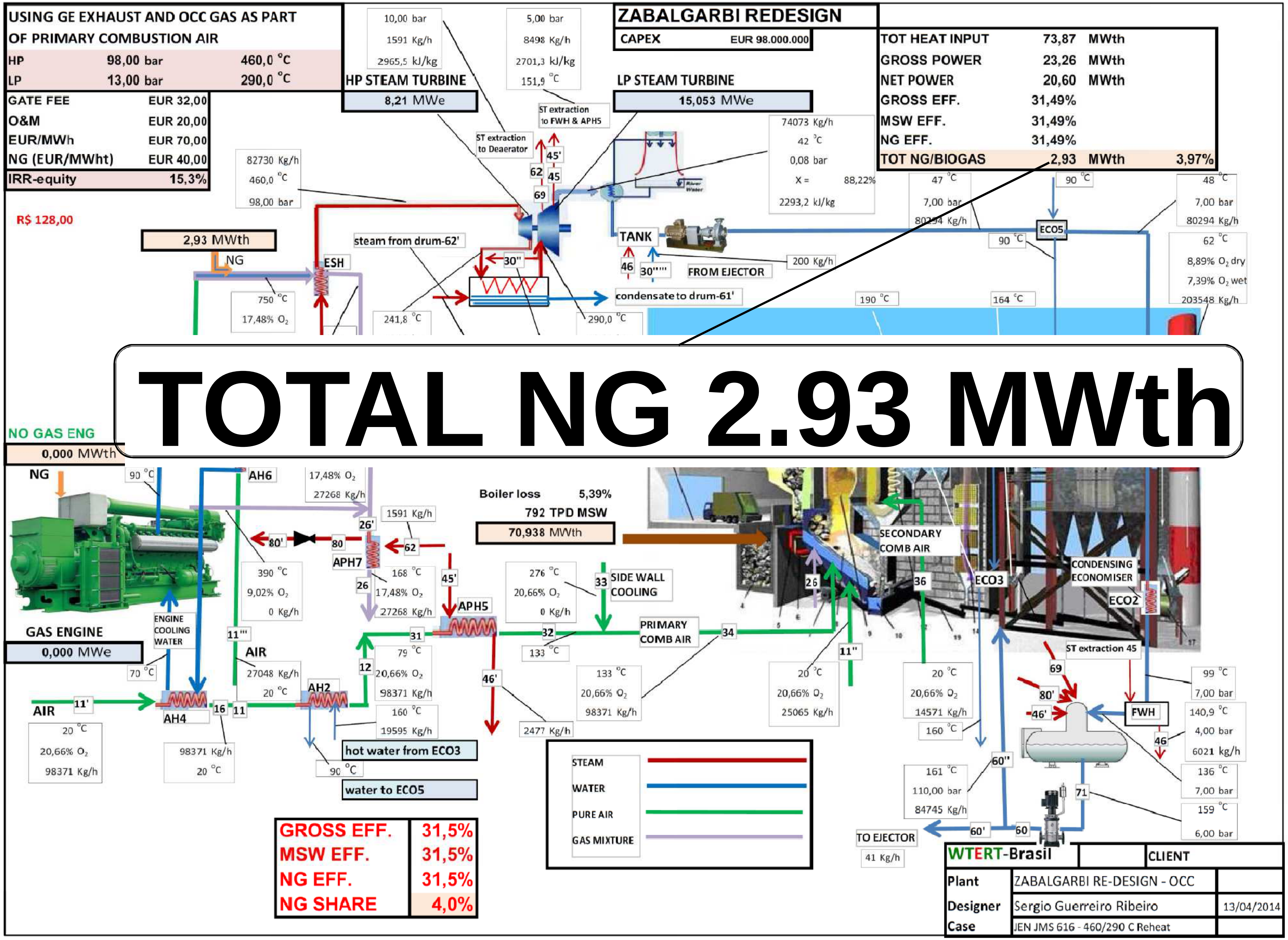


Figure 6 –OCC with Reheat Steam Cycle using Drum Extraction [8]

TOTAL NG 2.93 MWth



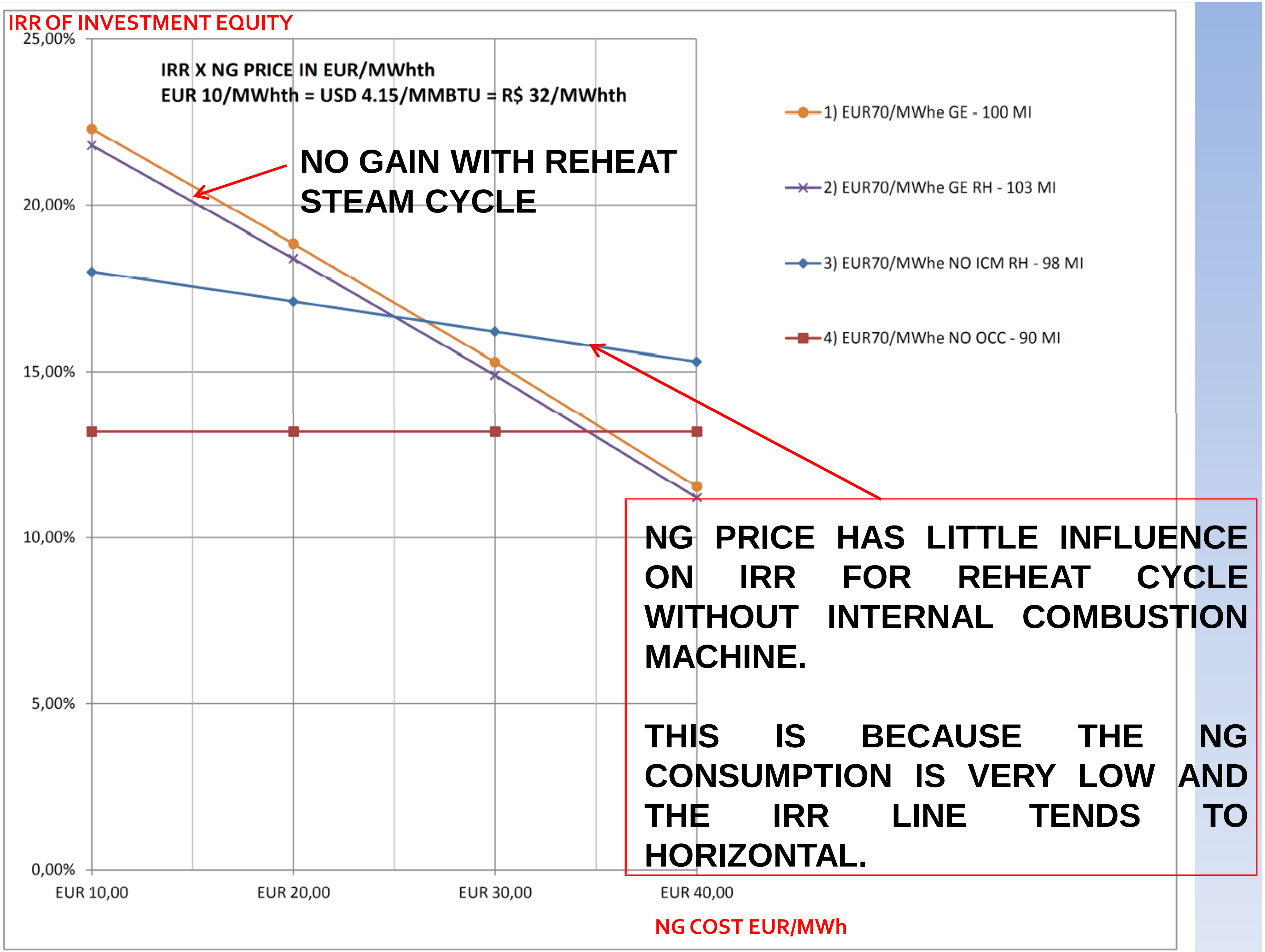


Figure 7 –IRR Comparison between GE, GT and no ICM OCC Solutions

CONCLUSIONS

1. THE OPTIMAL SOLUTION IS NOT THE ONE WITH HIGHEST THERMODYNAMIC EFFICIENCY

2. DEPENDING ON DESIGN BOUNDARY CONDITIONS, IN SPECIAL NG COST AND ELECTRICITY SELLING PRICE, THE GOAL MUST BE THE LOWEST TIPPING FEE OR HIGHEST IRR

3. THE GAS ENGINE SOLUTION WITH EXTERNAL SUPERHEATING BY DUCT BURNER SEEMS TO BE THE BEST SOLUTION FOR MEDIUM TO HIGH NG COSTS

4. IN CASE NG COST GOES UP WE CAN TURN THE GE OFF AND PRE-HEAT THE COMBUSTION AIR USING ST EXTRACTION AS USUAL

5. TO START UP THE PLANT WE DON'T NEED EXTERNAL POWER SINCE WE CAN ALWAYS USE THE GE FOR INHOUSE POWER

6. IN CASE OF ST TRIP DUE TO TRANSMISSION LINE FAILURE WE CAN KEEP BURNING THE WASTE WITH GE POWER DUMPING THE STEAM TO THE CONDENSER.

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THANK YOU

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