Modeling and Optimization of Carbon-Negative NGCC Plant Enabled by Modular Direct Air Capture: *Supplementary Information* [extended]

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This document provides essential design data for the NGCC-PCC-DAC retrofit which serves as the basis of the optimization model in the main text.

The document is organized as follows. Section 1 covers the retrofit of the NGCC system and provides the simulation data for the NGCC system at different load factors. Section 2 includes the design of the PCC unit and the compression system. Section 3 includes the design for the DAC and post processing procedures. Section 4 provides an overview of the retrofit design and a summary of the system performance. Section 5 gives details on the costing of each unit. Finally, Section 6 describes the modeling of the start-up procedure.

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1. NGCC Retrofit Design

As stated in Section 2 of the main text, the aim of the retrofit design is to allow negative CO_2 emission and introduce extra flexibility into the system while maintaining high power output. In order to achieve these goals, it is necessary to reconfigure the NGCC steam system to support PCC solvent and DAC sorbent regeneration and re-evaluate the NGCC power output at different load levels with the new steam system. This section provides relevant information for these tasks and is organized as follows. The original NGCC from the B31A case in [5] was first modeled at full load in Section 1.1 Then, the NGCC performance was estimated as different partial loads in Section 1.2. Based on the modeling results, it was revealed that the pressure specifications for the PCC regenerator reboiler (73.5 psia) cannot be met by the default configuration at the minimum load level, which motivated the retrofit of the IP/LP crossover. The redesign of the steam system is discussed in Section 1.3.

1.1. NGCC Full Load Modeling

The B31A case from [5] describes the full load operation of a NGCC. For this project, a model was required that would predict performance of the NGCC at partial loads. To build such a model, an estimate of the heat transfer components on a $U \times A$ basis, where U is the overall heat transfer coefficient and A is the surface area of the heat transfer component, was required. The following information was supplied in [5]:

- steam flowrates, pressures, and temperatures entering and exiting the HRSG, and steam temperatures exiting the HRSG heat transfer components;
- the exhaust flowrate, composition, and exhaust temperature from the gas turbine.

To calculate $U \times A$ for each heat transfer component, the exhaust gas temperature profile through the HRSG needed to be calculated. To model the exhaust gas side heat transfer on each exchanger component, equations representing the heat capacity, thermal conductivity, and viscosity as a function of temperature were also required.

To generate this information, an AspenPlus model was built of the HRSG using the information from [5]. The gas turbine was not included as part of this model as the exhaust conditions given in [5] were used as an input to the HRSG. A process flow diagram (PFD) of the AspenPlus model is shown in Figure 1.

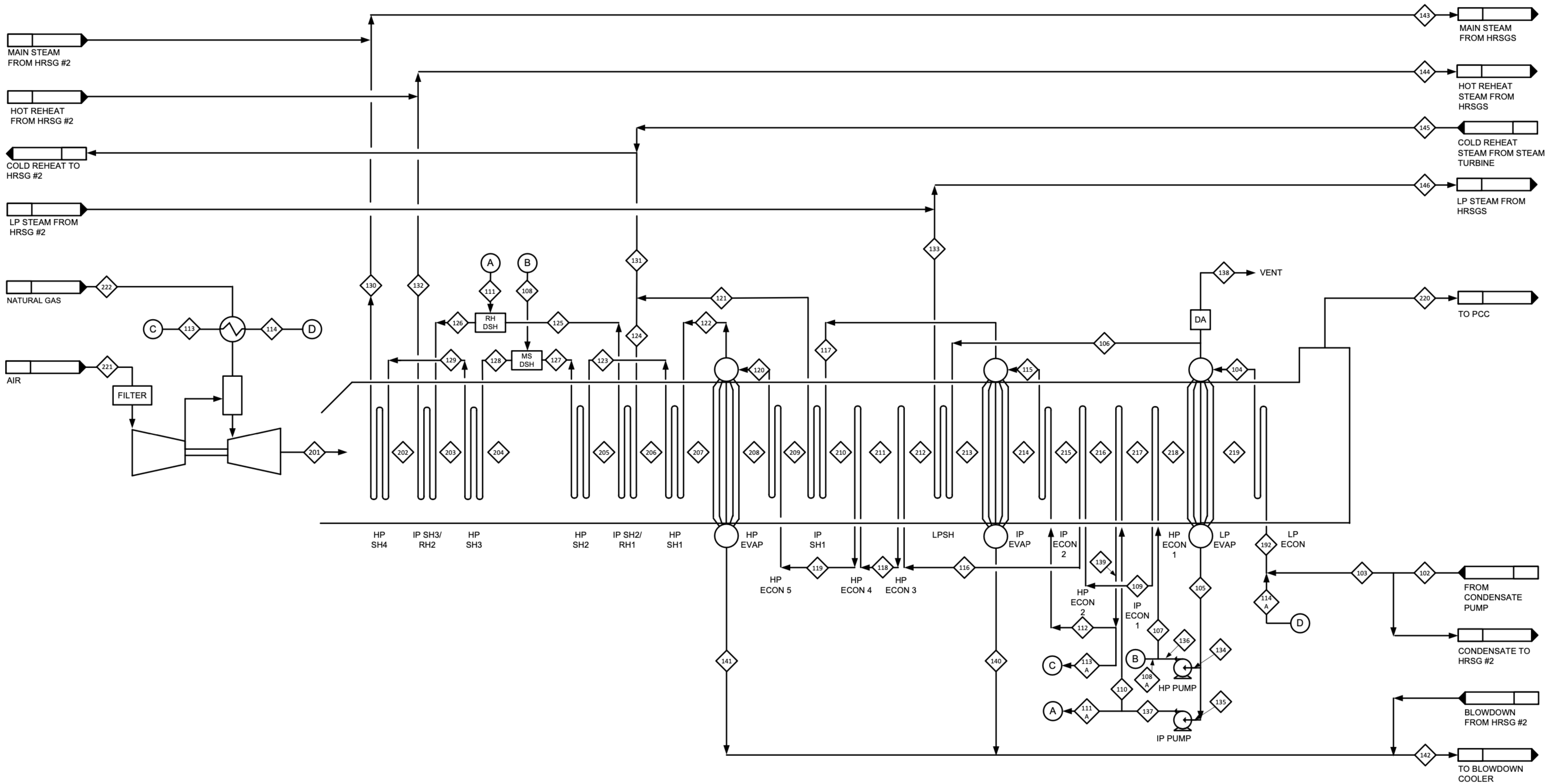

Figure 1: Process flow diagram for the HRSG model

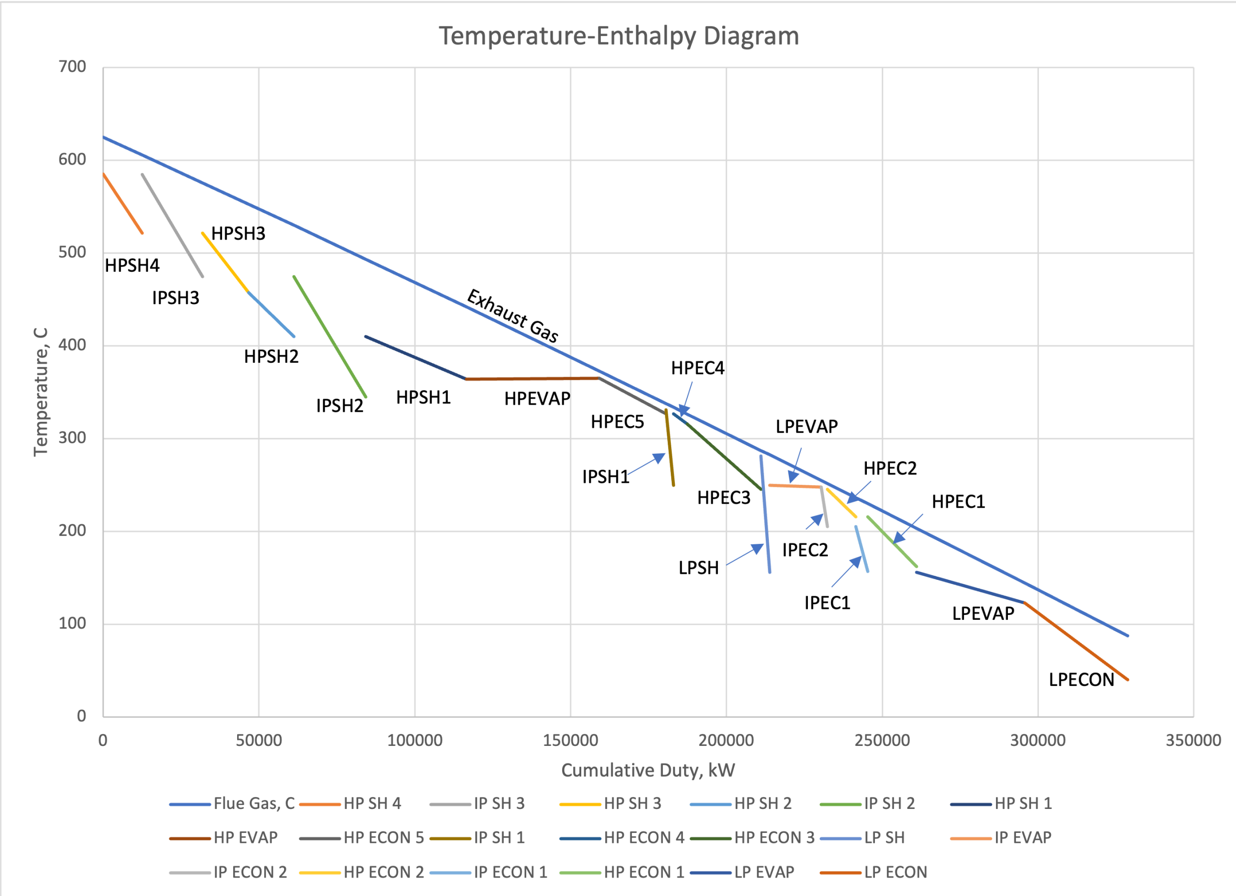

Figure 2: Temperature-enthalpy diagram for the HRSG model

The temperature-enthalpy (T-H) diagram is shown in Figure 2. It shows the temperature approach between the exhaust gas and the steam. There are several places in the HRSG where the temperature approach is approximately 6 °C. It was decided for this project to limit the minimum temperature approach to 8.3 °C (15 °F).

The heat exchanger performance information is shown in Table 1. It shows the duty from each heat transfer component as well as the temperatures of the exhaust gas and steam/water entering and exiting each component. Using the temperatures from the AspenPlus model, a log mean temperature difference (LMTD) is calculated. Dividing the heat duty by the LMTD gives the $U \times A$. This information was used to initialize the partial load HRSG model.

The overall unit performance in Table 2 was calculated primarily to validate the model compared to [5]. The steam turbine, condensate pump, IP Pump, and HP pump powers are calculated from AspenPlus. The remaining values are taken directly from [5] or were derived from the values in it.

Table 1: Heat exchanger performance information for HRSG

exchanger	duty kW	temperatures °C flue gas in	flue gas out	steam/water in	steam/water out	ΔT, hot °C	ΔT, cold °C	LMTD °C	$U \times A$ kW/°C
LP ECON	33,023	144.2	87.4	40.4	122.8	21	47	32.5	1015.1
LP EVAP	34,717	203.4	144.2	122.8	156.1	47	21.4	32.7	1062.2
HP ECON 1	15,659	229.9	203.4	162.1	215.6	14	41.3	25.5	614.0
IP ECON 1	3,758	236.2	229.9	157	205	31	72.9	49.1	76.5
HP ECON 2	9,161	251.6	236.2	215.6	245.6	6.1	20.7	11.9	768.0
IP ECON 2	1,918	254.9	251.6	205	247.8	7.1	46.6	21	91.4
IP EVAP	16,621	282.7	254.9	247.8	249.6	33	7.1	16.9	985.5
LP SH	2,747	287.2	282.7	156.1	281.1	6.1	127	39.8	69.0
HP ECON 3	23,682	326.5	287.2	245.6	315.6	11	41.7	23	1030.0
HP ECON 4	4,426	333.8	326.5	315.6	326.7	7.1	11	8.9	496.8
IP SH 1	2,403	337.8	333.8	249.6	331.1	6.7	84.2	30.6	78.6
HP ECON 5	21,345	372.8	337.8	326.7	365	7.8	11.1	9.3	2288.9
HP EVAP	42,713	441.9	372.8	365	364.3	78	7.8	30.3	1408.3
HP SH 1	32,300	493.4	441.9	364.3	410	83	77.6	80.5	401.3
IP SH 2	23,090	529.9	493.4	344.9	474.4	55	149	94.5	244.5
HP SH 2	14,523	552.7	529.9	410	457.2	95	120	107.2	135.5
HP SH 3	14,710	575.6	552.7	457.2	521.7	54	95.4	72.7	202.3
IP SH 3	19,396	605.7	575.6	474.4	584.4	21	101	51.2	378.7
HP SH 4	12,511	625	605.7	521.7	585	40	84	59.3	210.9

Table 2: Overall unit performance for HRSG

gross power summary				
combustion turbine	477	MWe	477	MWe
HP steam turbine	58	MWe	58	MWe
IP steam turbine	87	MWe	87	MWe
LP steam turbine	121	MWe	121	MWe
total	743	MWe	743	MWe

auxiliary load summary				
circulating water pumps	2785	kWe	2785	kWe
combustion turbine auxiliaries	1020	kWe	1020	kWe
condensate pumps	175	kWe	175	kWe
cooling tower fan	1447	kWe	1447	kWe
IP pump	115	kWe	115	kWe
HP pump	2712	kWe	2712	kWe
ground water pump	260	kWe	260	kWe
miscellaneous balance of plant	570	kWe	570	kWe
SCR	2	kWe	2	kWe
steam turbine auxiliaries	202	kWe	202	kWe
transformer losses	2260	kWe	2260	kWe
total auxiliaries	11548	kWe	11548	kWe
	12	MWe	12	MWe

net power	732	MWe	732	MWe
natural gas feed	93,272	kg/h	205,630	lb/h
HHV thermal input	1,355	MWth	4,623	MMBTU/h
Gas turbine heat rate	10,225	kJ/(kW*h)	9,692	BTU/(kW*h)
gas turbine efficiency	35.20%		35.20%	
steam turbine heat rate	4,445	kJ/(kW*h)	4,214	BTU/(kW*h)
steam turbine cycle efficiency	81.00%		81.00%	
overall unit heat rate	6,563	kJ/(kW*h)	6,221	BTU/(kW*h)
	54.80%		54.80%	

1.2. NGCC Partial Load Modeling

1.2.1. Gas Turbine Modeling

From [5] for case B31A, the exhaust flow and exhaust temperature were given in Exhibit 5-15 [5]. The type of gas turbines was reported as "two state-of-the-art 2017 F-class gas turbines". Therefore, since this was a "generic" turbine it was not possible to approach a manufacturer for turndown information. In the absence of this information, the graph in Figure 3 from [8] was used to determine the exhaust flow, temperature, and natural gas flowrate as the gas turbine load changed.

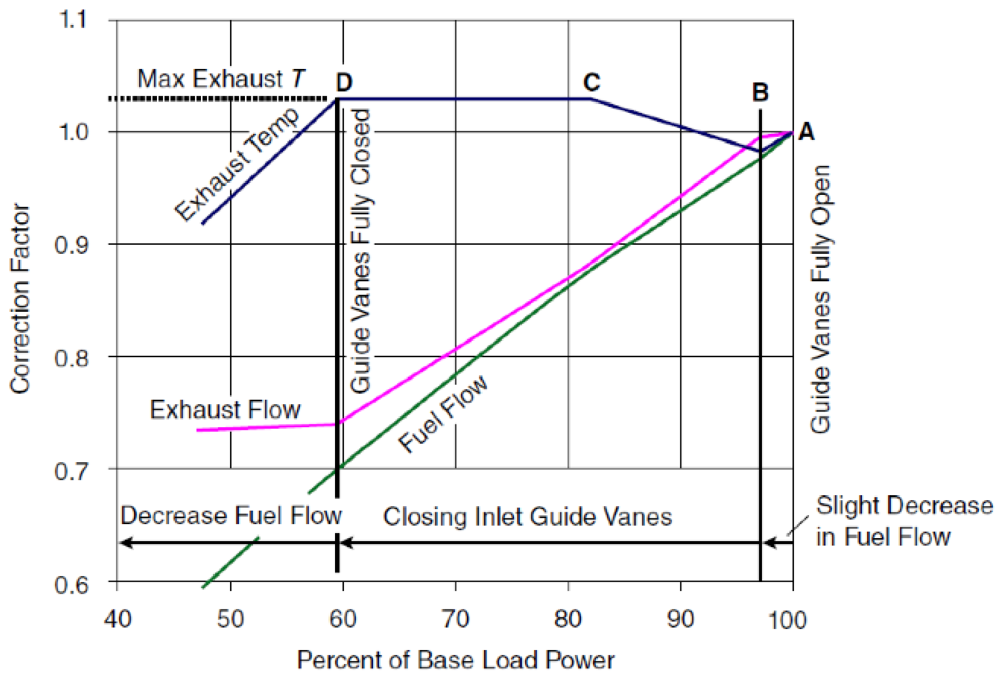

Figure 3: Gas turbine performance correction curve at partial loads

As the gas turbine reduces load, the turbine's inlet guide vanes are closed to reduce the exhaust flow while the fuel flow is being reduced to maintain a relatively constant temperature at the inlet of the HRSG so that the main and reheat steam temperatures can be maintained. At 60% on this curve, the inlet guide vanes are in their fully closed position and further reductions in load are accomplished by reducing the fuel flow. Since the gas turbine is rotating at a constant speed, the volumetric flowrate of the air entering the turbine below 60% load would remain relatively constant, and the exhaust temperature would fall with the reduced fuel flow. Using the 100% load flowrates from Exhibit 5-15 of [5] and these correction curves, the exhaust flowrates, exhaust temperatures and fuel flowrate shown in Table 3 were calculated and were used as the exhaust conditions for the partial load cases.

Based on the flowrates from Table 3, the exhaust gas compositions in Table 4 were calculated and used in PCC modeling.

From the information given in Table 3, the open cycle heat rate and efficiency on a LHV basis can be estimated assuming a LHV heat rate for the natural gas of 47,141 kJ/kg (20,267

Table 3: Gas turbine exhaust and fuel conditions for partial load cases (one turbine)

load factor %	exhaust flow kg/h (lb/h)	fuel flow kg/h (lb/h)	exhaust temperature °C (°F)
100	1,965,464 (4,329,215)	46,678 (102,815)	625 (1157)
90	1,859,329 (4,095,437)	43,490 (95,793)	628 (1163)
80	1,711,329 (3,769,448)	40,302 (88,770)	644 (1192)
70	1,586,129 (3,493,667)	36,661 (80,751)	644 (1192)
60	1,462,305 (3,220,936)	32,959 (72,598)	644 (1192)
50	1,443,319 (3,181,973)	28,891 (63,694)	588 (1090)

Table 4: Gas turbine exhaust gas composition

load factor	Mole %				
	Ar	CO_2	N_2	O_2	H_2O
100%	0.88	4.23	74.07	11.46	9.35
90%	0.88	4.17	74.12	11.6	9.23
80%	0.88	4.2	74.1	11.54	9.29
70%	0.88	4.12	74.16	11.71	9.13
60%	0.88	4.02	74.23	11.93	8.94
50%	0.89	3.58	74.57	12.9	8.06

BTU/lb). This heat rate information is shown in Table 5.

There are two possible scenarios for the 50% gas turbine electrical load case-2 × 50% and 1 × 100%. The 2 × 50% case has a combined estimated exhaust flow entering the HRSGs of 2,886,638 kg/h (6,363,946 lb/h) vs 1,965,464 kg/h (4,329,215 lb/h) for the 1 × 100% case. Since the 2 × 50% case has a higher exhaust flowrate, more steam would be generated in the two HRSGs, increasing the steam turbine power.

1.2.2. HRSG Modeling

The overall heat transfer coefficient for an exchanger in a HRSG is dominated by the gas side heat transfer coefficient since the heat transfer coefficient on the steam/water side is typically at least an order of magnitude higher. Recognizing this, the approach described by [3, 4] was utilized for the partial load modeling based on the stream definitions shown in Figure 1.

1. *Calculate the steam/water side heat duty for the exchanger.* For the 100% case, the steam/water temperatures were taken from [5] and AspenPlus and the enthalpies were taken from the steam tables.

$$\text{steam duty} = m_\mathrm{c} \cdot (H_\mathrm{o} - H_\mathrm{i}), \tag{1}$$

where

Table 5: Estimated gas turbine performance at partial loads

load factor %	gas turbine electrical power kW	LHV heat input to gas turbine GJ/h (MMBTU/h)	LHV Heat Rate kJ/kWh (BTU/kWh)	LHV efficiency %
100	238,500	2,198 (2,084)	9,217 (8,737)	39.1
90	214,650	2,048 (1,941)	9,542 (9,045)	37.7
80	190,800	1,898 (1,799)	9,948 (9,429)	36.2
70	166,950	1,727 (1,637)	10,342 (9,803)	34.8
60	143,100	1,522 (1,471)	10,847 (10,282)	33.2
50	119,250	1,362 (1,291)	11,420 (10,825)	31.5

Table 6: Partial load cases operating configuration

case number	*total* load factor	operating gas turbines and single load factor
1	100%	2 × 100%
2	90%	2 × 90%
3	80%	2 × 80%
4	70%	2 × 70%
5	60%	2 × 60%
6	50%	2 × 50%
7	50%	1 × 100%
8	40%	1 × 80%
9	30%	1 × 60%
10	25%	1 × 50%

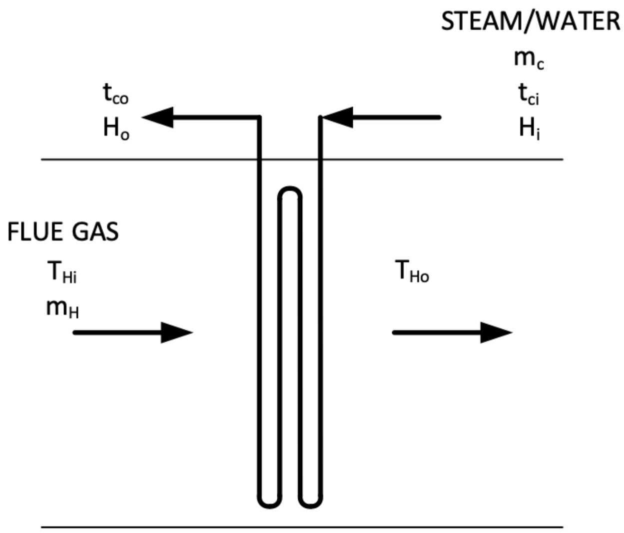

Figure 4: Heat transfer stream designations

- m_c: the mass flow of the cold stream (steam or water)
- H_o: the outlet enthalpy of the cold stream
- H_i: the inlet enthalpy of the cold stream

2. *Increase exhaust gas duty for heat loss.* It was assumed that there was a 0.5% heat loss through the HRSG casing, so the exhaust gas duty was increased by this amount. The mass flow, and the temperatures in the HRSG were taken from [5] or calculated by AspenPlus and the physical properties of the exhaust gas were determined from AspenPlus.

$$\text{exhaust gas duty} = \text{steam duty}/0.995. \tag{2}$$

$$T_{H_o} = T_{H_i} - \frac{\text{exhaust gas duty}}{m_H \cdot c_{p,\text{avg}}}, \tag{3}$$

where

- T_{H_i}: the inlet temperature of the hot stream (exhaust gas)
- T_{H_o}: the outlet temperature of the hot stream (exhaust gas)
- m_H: the exhaust gas mass flow
- $c_{p,\text{avg}}$: the average specific heat of the exhaust gas

3. *Calculate the log mean temperature difference (LMTD).* Assuming counterflow heat transfer, the LMTD is calculated with the following equation.

$$\text{LMTD} = \frac{(T_{H_i} - t_{c_o}) - (T_{H_o} - t_{c_i})}{\ln\left[\frac{(T_{H_i} - t_{c_o})}{(T_{H_o} - t_{c_i})}\right]}, \tag{4}$$

where

- t_{c_i}: the inlet temperature of the cold stream (steam/water)
- t_{c_o}: the outlet temperature of the cold stream (steam/water)

4. *Calculate the K factor for each exchanger.* From [3, 4], K is a constant and reflects the geometry of an exchanger bundle.

$$\text{exhaust gas duty} = U \cdot A \cdot \text{LMTD}, \tag{5}$$

where

- U: the overall heat transfer coefficient
- A: the heat transfer area of the heat exchanger

As previously mentioned, the heat transfer is dominated by the gas side h_o:

$$\frac{\text{exhaust gas duty}}{\text{LMTD}} \approx h_o \cdot A \tag{6}$$

The outside heat transfer coefficient is defined as [3, 4]:

$$h_\text{o} = \frac{k}{D} \cdot C \cdot \text{Re}^{0.65} \cdot \text{Pr}^{0.33}, \tag{7}$$

where

- h_o: the film coefficient on the outside of the exchanger tube
- k: the thermal conductivity of the exhaust gas
- D: the outlet diameter of the tube
- C: a coefficient that is defined by the bundle geometry (staggered tubes, spacing, etc.)
- Re: the gas side Reynolds number
- Pr: the gas side Prandtl number

The Reynolds number can be defined as [6]:

$$\text{Re} = \frac{D_e \cdot G}{\mu}, \tag{8}$$

where

- D_e: the equivalent diameter of the tube
- G: gas side mass flux
- μ: gas viscosity

The gas side mass flux is defined as:

$$G = \frac{m_H}{\text{flow area}_\text{bundle}}, \tag{9}$$

where flow $\text{area}_\text{bundle}$ is the open area of the tube bundle.

The Prandtl number is defined as:

$$\text{Pr} = \frac{c_p \cdot \mu}{k} \tag{10}$$

Substituting and rearranging terms:

$$h_o \cdot A = K \cdot m_H^{0.65} \cdot \frac{c_p^{0.33} \cdot k^{0.67}}{\mu^{0.32}} \tag{11}$$

The last term represents the changes in the physical properties of the exhaust gas, which are a function of the exhaust gas temperature. It was defined as F_g. Therefore,

$$\text{exhaust gas duty} = K \cdot m_H^{0.65} \cdot F_g \cdot \text{LMTD} \tag{12}$$

This approach greatly simplifies the heat transfer calculations for the off-design cases since the physical geometry of the HRSG is unknown. The 100% flow case from [5] and the information from AspenPlus were used to calculate the K values for each heat exchanger.

- The steam flowrates and the steam/water temperatures were taken from [5].
- From this the steam/water duty for each heat exchanger was calculated.
- Based on a 0.5% heat loss, the exhaust gas duty was calculated.
- The mass flow of the exhaust gas was given in [5].
- The exhaust gas temperatures were calculated in the AspenPlus model as well as the values for heat capacity, thermal conductivity, and viscosity. From this information F_g was calculated for based on the exhaust gas temperature.
- With the exhaust gas temperatures calculated, the LMTD for each exchanger could be calculated.

With this information, the K values for each exchanger at the full gas turbine electric load were determined. Since the K value is defined by the tube bundle geometry, it is constant regardless of the gas flowrate through the HRSG.

1.2.3. Steam Turbine Modeling

Each of the steam turbines was modeled as a constant volumetric flow isentropic expansion. The mass flow of the steam was determined in the HRSG model. With each model iteration, the pressure at the inlet of each turbine section (HP and IP) was adjusted so that the volumetric flowrate of the steam entering each turbine section was held constant. As the gas turbine electrical load decreased between cases, there would be less heat available in the HRSG to raise steam. Therefore, the mass flow of the steam to the steam turbine would decrease. The model would reduce the steam pressure to maintain a constant volumetric flow at the inlet.

The isentropic efficiency for the HP, IP and LP turbines at full load was derived from the information in [5]. The estimated isentropic efficiency for the HP turbine was 90.9%, the IP turbine was 92.3% and the LP turbine was 91.7%. As the flowrate of the steam decreased through each turbine section, the efficiency was adjusted as described in [12].

For the cases where the partial load performance was evaluated without the PCC or DAC systems, the same approach was taken with the LP turbine as described above with the HP and IP turbines: the pressure exiting the IP turbine was adjusted so that the volumetric flow of the steam entering the LP turbine was constant. In the cases where the PCC and DAC systems were included, it was assumed that the original LP turbine would be replaced with a much smaller one due to the amount of LP steam required for the PCC system. For these cases, the volumetric flow of steam entering the LP turbine for the "min DAC" mode, full load case determined the "design" volumetric flow. As the gas turbine load decreased, the pressure at the outlet of the IP Turbine would be adjusted to maintain a constant volumetric flow entering the LP turbine.

Steam seal flows and packing leaks were also calculated per the methodology described in [12].

1.2.4. No Carbon Capture Performance

Baseline performance of the unit without carbon capture as the load changes is shown in Table 7. Due to the addition of piping pressure drops between the HRSG and steam turbine and an assumed heat loss in the HRSG there are minor differences in performance between these results and B31A.

- The gas turbine gross electrical output is the percentage of load for the turbine. At full load, each turbine produces 238.5 MW. At 50% load, the electrical power for each turbine is $238.5 \cdot 0.5 = 119.3$ MW.
- Based on the gas turbine load, the exhaust flow and exhaust temperature were derived from Figure 3. This exhaust gas flow and temperature were used as an input into the HRSG model to calculate the HP, IP, and LP steam flows. These flows were used in the steam turbine model to produce the steam turbine gross power.
- The pump powers were calculated based on the water flowrate and the pressure profile from B31A.
- The cooling tower fan power and circulating water pump power were estimated based on comparing the condenser duty for each case with the condenser duty of B31A and the power for the cooling tower fans and circulating water pumps in B31A.
- The remaining electrical loads were assumed to be constant, using the values from B31A.
- The natural gas flow was derived from Table 5 based on the gas turbine load.

From 100% gas turbine load to 50% gas turbine load, the decrease in efficiency is primarily due to the efficiency decrease of the gas turbine as shown in Table 5. Comparing the $1 \times 100\%$ case and the $2 \times 100\%$, the difference in overall plant efficiency between these cases is primarily due to the decreased efficiency of the steam turbine at the partial load.

Table 7: NGCC performance without carbon capture

total load factor		100%	90%	80%	70%	60%	50%	50%	40%	30%	25%
Configuration		2 × 100%	2 × 90%	2 × 80%	2 × 70%	2 × 60%	2 × 50%	1 × 100%	1 × 80%	1 × 60%	1 × 50%
gas turbine	kW	477,000	429,300	381,600	333,900	286,200	238,500	238,500	190,800	143,100	119,250
steam turbine	kW	253,213	240,250	223,906	206,302	189,133	173,929	119,282	105,891	89,482	77,289
HP	kW	51,972	49,071	45,319	41,479	37,770	34,324	23,382	20,609	17,153	14,595
IP	kW	81,254	77,718	73,429	68,546	63,672	59,624	43,730	39,547	34,337	30,062
LP	kW	119,987	113,461	105,158	96,277	87,691	79,982	52,170	45,735	37,992	32,632
total gross power	kW	730,213	669,550	605,506	540,202	475,333	412,429	357,782	296,691	232,582	196,539
circulating water pumps	kW	2,737	2,618	2,465	2,298	2,134	1,898	1,424	1,286	1,114	1,003
combustion turbine auxiliaries	kW	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
condensate pumps	kW	178	170	159	148	137	127	89	80	69	62
cooling tower fans	kW	1,422	1,360	1,281	1,194	1,109	986	740	668	579	521
feedwater pumps	kW	5,434	5,044	4,540	4,026	3,554	3,086	1,898	1,633	1,318	1,107
ground water pumps	kW	255	244	229	214	199	177	132	120	104	93
miscellaneous balance of plant	kW	570	570	570	570	570	570	570	570	570	570
SCR	kW	2	2	2	2	2	2	2	2	2	2
steam turbine auxiliaries	kW	200	200	200	200	200	200	200	200	200	200
transformer losses	kW	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250
total auxiliaries	kW	14,068	13,478	12,716	11,922	11,175	10,316	8,325	7,828	7,226	6,828
net power	kW	716,145	656,072	592,791	528,279	464,158	402,112	349,457	288,862	225,356	189,711
natural gas flow	lb/h	205,630	191,585	177,541	161,502	145,195	127,388	102,815	88,770	72,598	63,694
	kg/h	93,356	86,980	80,604	73,322	65,919	57,834	46,678	40,302	32,959	28,917
heat input to turbine(s)	MMBTU/h	4,616	4,300	3,985	3,625	3,259	2,859	2,308	1,993	1,630	1,430
	GJ/h	4,869	4,537	4,204	3,824	3,438	3,017	2,435	2,102	1,719	1,508
HHV net plant heat rate	BTU/kWh	6,445	6,555	6,723	6,862	7,021	7,111	6,604	6,898	7,231	7,536
	kJ/kWh	6,799	6,915	7,092	7,239	7,408	7,502	6,967	7,277	7,629	7,951
HHV net plant efficiency	%	52.9%	52.1%	50.8%	49.7%	48.6%	48.0%	51.7%	49.5%	47.2%	45.3%
CO_2 emission rate	tonne CO_2/MWh	0.361	0.367	0.376	0.384	0.393	0.398	0.370	0.386	0.405	0.422

1.3. Low Pressure Steam System Redesign

The goal of this project was to have a "flexible" system which could either maximize the CO_2 removal or maximize electrical power based on the current economic conditions. As discussed next in Section 1.3.1, the conventional NGCC IP/LP crossover cannot support the PCC regeneration at low loads. To accommodate this goal, the conventional NGCC IP/LP crossover duct was replaced with a LP steam distribution system. The LP steam system supplied steam to the following systems:

- PCC system: the steam for the PCC regenerator reboiler is supplied from the LP steam system. The amount of steam supplied depends on the amount of methane combusted in the gas turbine and the CO_2 produced. Therefore, the steam flow to the PCC system is only dependent on the gas turbine load.
- DAC system: steam for the DAC system is generated using LP steam. If the price for removing CO_2 is high relative to that of electrical power, the LP steam that is not utilized by the PCC system will flow to the DAC Steam Generation system to produce steam for the DAC system.
- LP Steam Turbine: If the price for removing CO_2 is low relative to that of electrical power, the LP steam not utilized by the PCC system will flow to the LP turbine to generate electricity.

It was decided that the steam generated in the DAC steam generation system would be a separate loop than that of the HRSG steam/condensate system for the following reasons:

- The steam pressure required by the DAC system is low (<10 psig). Therefore, the water quality requirements are less stringent than that required by the HRSG.
- Approximately half of the steam supplied to the DAC system would be lost to the atmosphere during regeneration. If the water was taken from the HRSG steam cycle, the size of the water treatment system would have to be substantially increased to provide this degree of makeup.
- The recovered DAC condensate will be saturated with CO_2 and would be acidic. Maintaining the HRSG water chemistry when combining the HRSG and DAC condensate with this concentration of CO_2 in the water would be challenging.

It was assumed that there would be no changes to the B31A gas turbines, HRSG or the HP Steam Turbine. The IP turbine, LP turbine, condenser and the balance of plant systems would be modified as required.

1.3.1. Increasing the LP Steam Pressure

The steam conditions required by the PCC regenerator reboiler were saturated steam at 73.5 psia at all loads. The IP turbine exhaust pressure in cases B31A and B31B was 75 psia at full load. As the gas turbine reduces load, the mass flow of steam produced by the HRSG and flowing to the steam turbine decreases. Since a steam turbine is a constant volume machine, the steam pressure decreases with reduced gas turbine load to maintain a constant volumetric flow through the steam turbine. It was estimated that if the IP/LP crossover

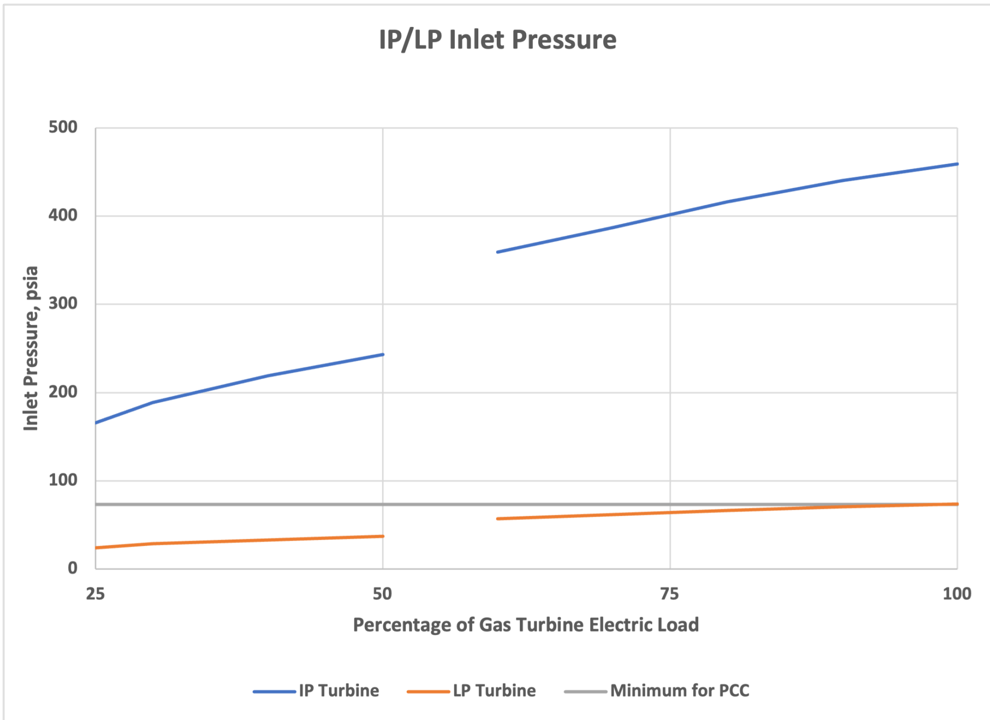

Figure 5: Estimated steam turbine inlet pressures based on B31A

pressure was 75 psia at full load, then at 25% gas turbine load (1 gas turbine operating at 50% load), the pressure in the IP/LP crossover would fall to 24 psia as shown in Figure 5.

To meet the criteria that the pressure of the steam at the exit of the IP turbine would be at least 73.5 psia at 25% gas turbine load, the exhaust pressure of the IP turbine was increased to 168 psia at full load as shown in Figure 6. This had two consequences to the flowsheet:

- Because the steam exiting the IP turbine is at a higher pressure than B31A, the temperature of the steam exiting the IP turbine would be hotter. In B31A, the steam exiting the IP turbine is 587 °F at 75 psia. At an exhaust pressure of 168 psia, the exhaust temperature is 797 °F.
- Also, because the pressure of the LP steam exiting the IP turbine is 168 psia and it was assumed that no modifications were made to the HRSG, the 75 psia steam generated within the HRSG was at too low of a pressure to enter the LP steam header and would be handled separately.

1.4. LP Steam Flowsheet

The low-pressure (LP) steam flowsheet to support the PCC and DAC system is shown in Figure 7 to Figure 9. The flowsheet in Figure 7 illustrates the scenario where it is desired to maximize the electrical power output. The steam and condensate lines that are being supplied to the PCC system components (regenerator reboiler, reclaim and CO_2 drying)

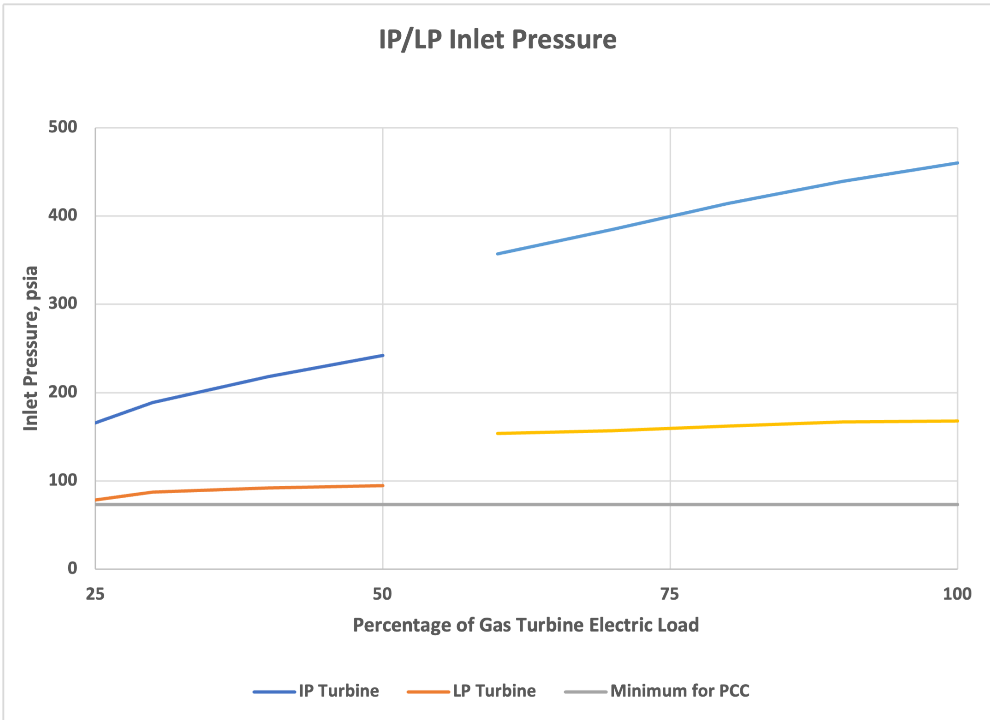

Figure 6: Raising ip outlet pressure for pcc system at partial loads

are colored in red. Since the flowrate of these streams is a function of the CO_2 that is being captured in the PCC system, they will not change whether the unit is producing the maximum power or removing the maximum CO_2. Notice that the steam that flows to the PCC regenerator reboiler is desuperheated in HX-5 by generating steam for the DAC system. After the LP steam is utilized in the PCC regenerator reboiler, the condensate is combined with the condensate from the reclaim/CO_2 drying and used to generate additional DAC steam in the condensate cooler, HX-3. Therefore, even for the “min DAC” case some DAC steam is being generated and the unit can remove CO_2 from the atmosphere.

The blue lines in Figure 7 represent the steam and condensate that are utilized for generating power in the LP Turbine. The LP steam that is not being utilized by the PCC system flows to the LP turbine from the IP/LP crossover. Since the pressure of this steam is higher than the steam being generated by the HRSG, this steam is expanded in LP Turbine 1 to match the pressure of the LP steam exiting the HRSG. These two streams combine and flow through LP Turbine 2. The exhaust steam is condensed in HX-6 and returned to the HRSG. A small portion of the LP steam from the HRSGs is supplied to the decarbonator to degas the DAC condensate.

The orange lines in Figure 7 represent the steam/condensate for DAC system. The steam that is generated in the natural circulating steam generators (HX-3 and HX-5) is separated from the circulating water in the DAC steam drum and then used to regenerate the DAC system. It is expected that half of the steam entering the DAC system would be lost to the atmosphere and the other half would be recovered in the DAC condensate collection drum and recycled. Makeup water would be added to the DAC condensate collection drum to maintain the water inventory necessary in the DAC steam generation system. The combined stream would be pumped through a DAC condensate treatment system which will remove any impurities from the recovered condensate and adjust the pH of the water. The condensate leaving the DAC condensate treatment system would be pre-heated in HX-8 using the warm condensate from HX-3 before entering the decarbonator. This preheating would minimize the amount of steam needed to heat the condensate to saturation temperature in the decarbonator. LP steam from the HRSGs would be used to complete the heating of the DAC condensate to saturation in order to "degas" the CO_2 that was dissolved into the water during the regeneration process. The condensate exiting the decarbonizer would be pumped back to the DAC steam drum to be used as feedwater for the natural circulation steam generation system.

To increase the generation of the DAC steam, the LP steam used in the LP Turbine for the "min DAC" case would be re-directed to HX-7 to generate additional DAC steam. Figure 8 shows the scenario where the LP steam system would be transitioning from "min DAC" to "max DAC" and 50% of the steam from the IP/LP crossover and 50% of the LP steam from the HRSGs (after extracting the steam for the decarbonator) was being diverted to HX-7 and the remaining steam to the LP turbine.

As the combined steam flows through HX-7 additional DAC steam would be generated. The exchanger would condense the LP steam using its latent heat to generate DAC steam. The condensate from HX-7 would combine with the condensate from the PCC system, increasing the steam generation in HX-3. The combined condensate streams provide preheating for the DAC condensate in HX-8 and would be returned to the HRSG.

Figure 9 shows the scenario where all the LP steam that was not being utilized by the PCC system would be utilized to generate DAC steam in HX-7. In this scenario, there would be no steam flowing to the steam turbine.

The change in gross power generated as the split of the DAC steam from the LP Turbine to HX-7 is varied is shown in Figure 10. Varying the LP steam flow to the LP Turbine from 0 to 100% would increase the total gross power by approximately 65 MW, approximately 10% of the total gross power. However, as shown in Figure 11, the amount of DAC steam generated increases as much as 400% if all the LP steam is diverted from the LP Turbine to HX-7.

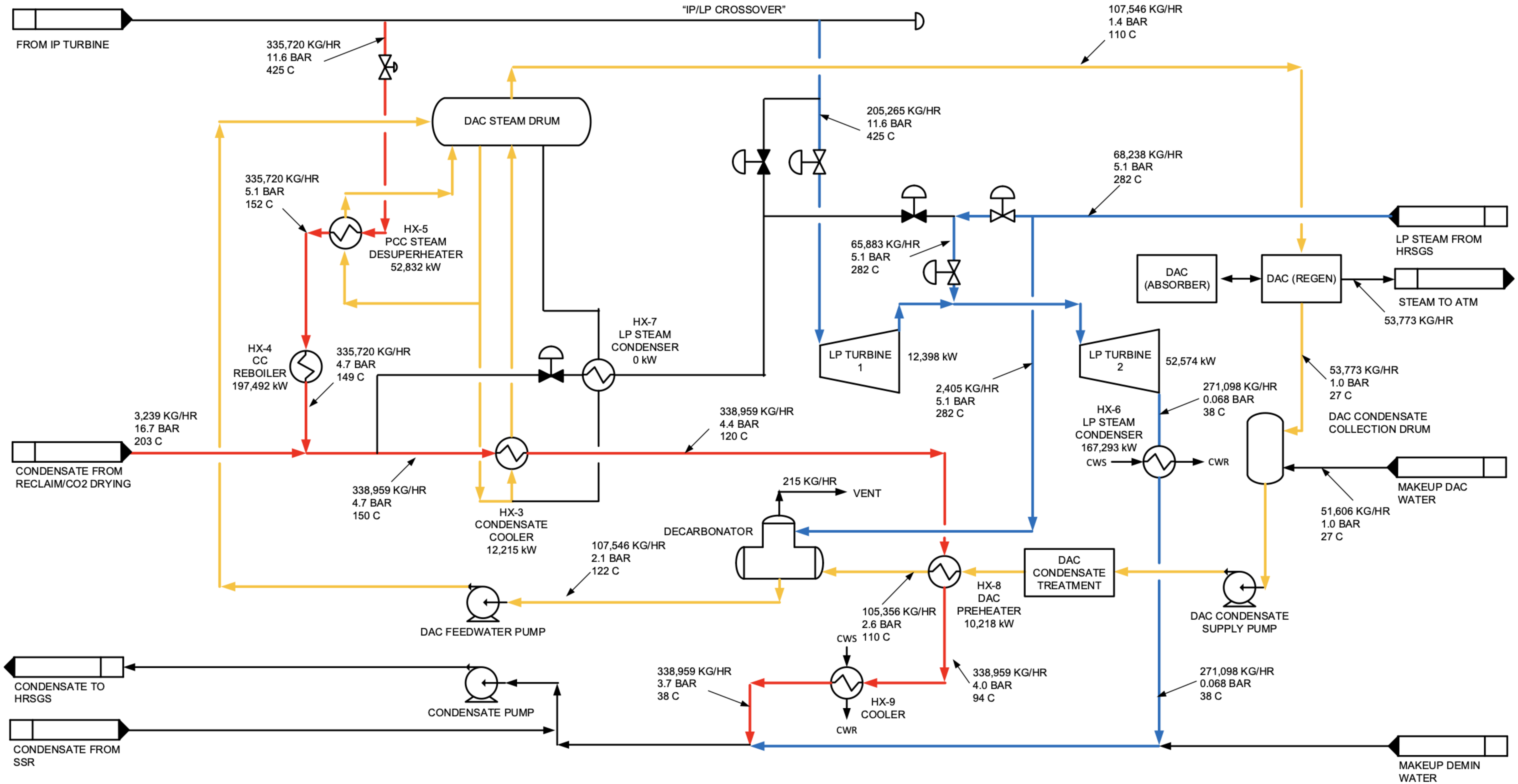

Figure 7: Flowsheet and HMB for "min DAC" mode

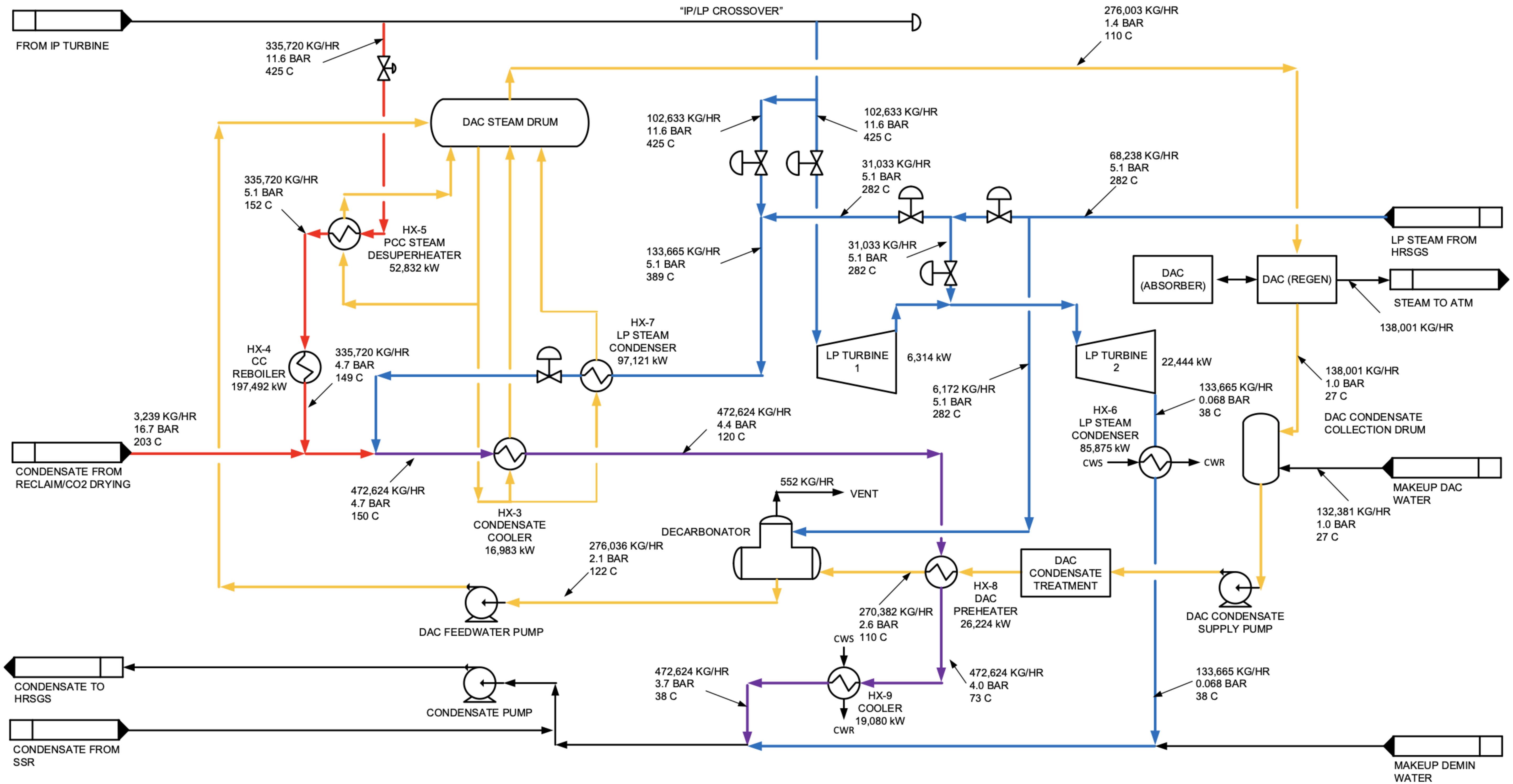

Figure 8: Flowsheet and HMB for "50 DAC" mode (50% of allocable steam goes to DAC)

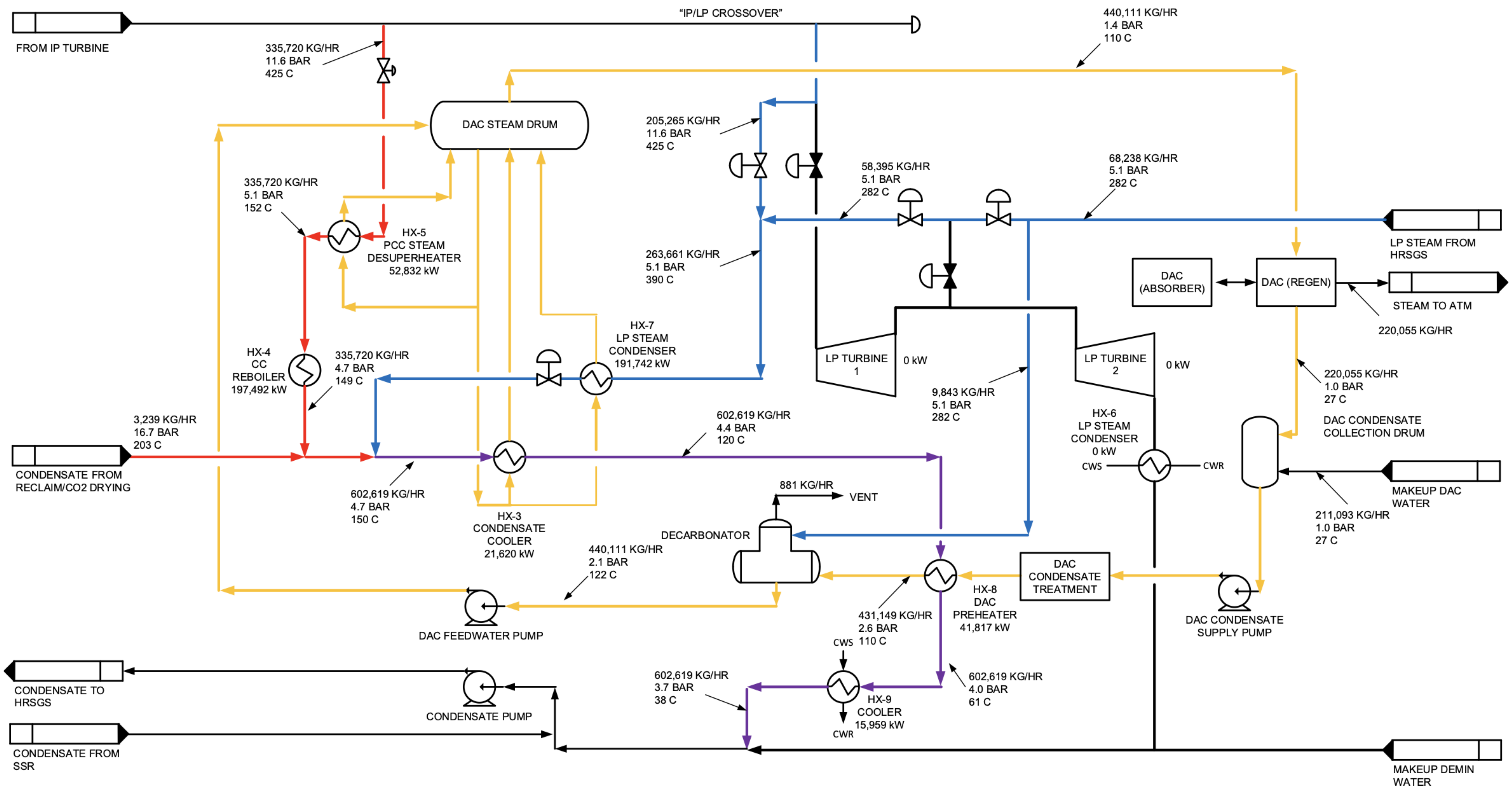

Figure 9: Flowsheet and HMB for "max DAC" Case

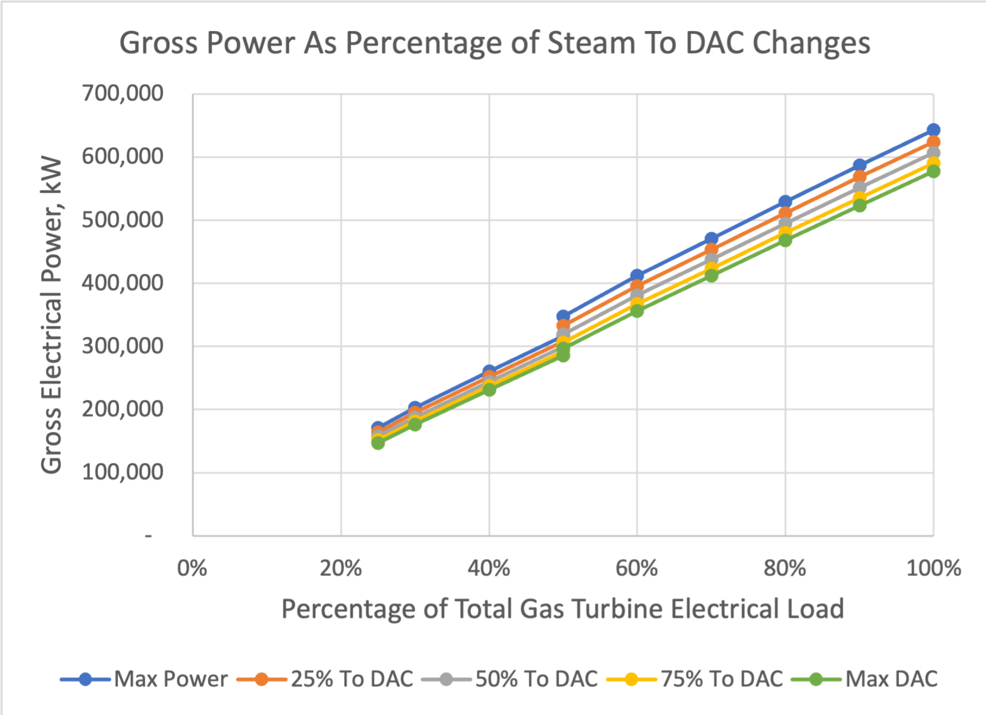

Figure 10: Gross power generated as the percentage of steam to the DAC changes

2. PCC & PCC Compression Design

The Post-combustion carbon capture (PCC) system for the NGCC flue gas was based upon Shell's Cansolv solvent, as presented in Case B31B of [5].

A block flow diagram (BFD) and associated stream tables for the PCC and PCC Compression systems are provided in Figure 14 and Table 17. A more detailed process flow diagram for the Cansolv PCC system is shown in Exhibit 5-3 of [5]. A detailed description of the Cansolv system for is found in Section 4.1.8 and Section 5.1.5 of [5]. For installation on an NGCC, the B31B PCC block consists of the following process areas:

- A booster fan to drive gas through the downstream equipment, including the direct contact cooler and absorber.
- A direct contact cooler that saturates and sub-cools the flue gas; no SO_2 polishing is required for the NGCC flue gas, as the pipeline natural gas sulfur content is very low.
- An absorber, consisting of a rectangular, acid-resistant, lined concrete structure containing stainless-steel packing, with the final stage of packing serving as the water-wash section. CO_2 is absorbed into the lean Cansolv solvent. The water-wash section removes volatiles and entrained amine from the flue gas, as well as condenses and retains water in the system. The flue gas treated in the water wash section is released to the atmosphere.

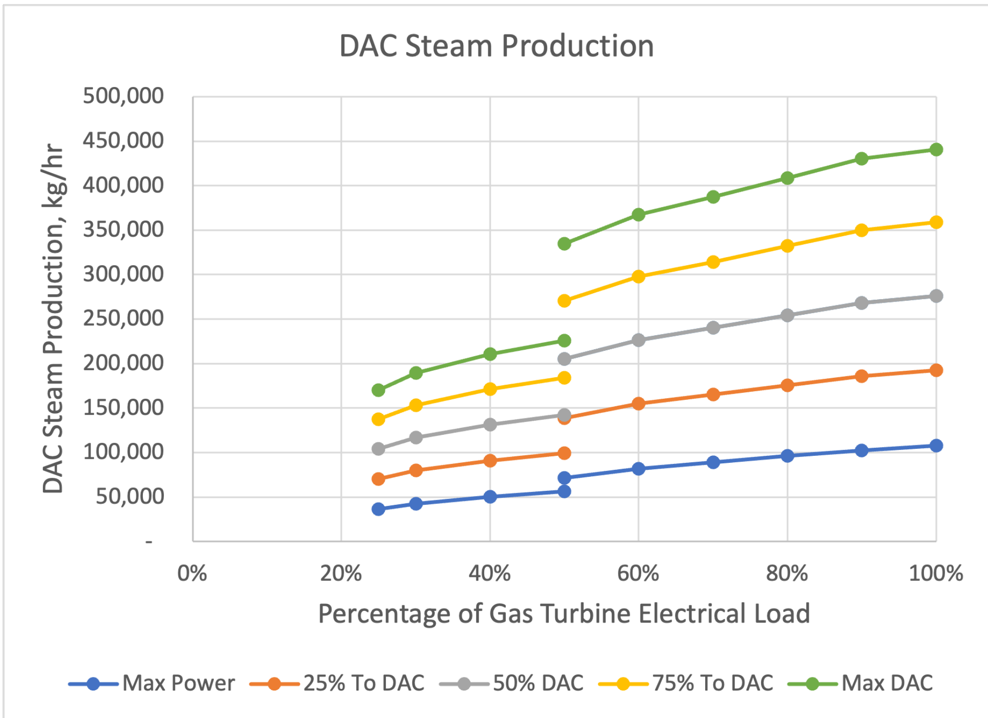

Figure 11: DAC steam production as the percentage of steam to the DAC changes

- An amine regeneration section, consisting of multiple parallel rich/lean heat exchangers, a stainless-steel stripper vessel with structured stainless-steel packing, and
- A thermal reclaimer to purify the amine to remove heat stable salts and other degradation products; the reclaiming process for the NGCC application includes an ion exchange reclaimer upstream of the reclaimer to remove excess heat stable salts.

The PCC compression system is described in Section 4.1.9 of [5], and it is represented in the block flow diagram in Exhibit 5-21 of [5]. The compression system is an eight-stage front-loaded centrifugal compressor which delivers a dense phase liquid at 30 °C to a pipeline inlet. The compressor includes intercooling for each stage, and water knockout for the first three stages. A trietheylne glycol (TEG) dehydration unit is included between stages 4 and 5 to meet the CO_2 purity requirement of $<$ 500 ppmv water.

2.1. PCC Design

The project team made the following decisions with respect to the design of the PCC Capture system:

- *Solvent selection.* Three solvents were evaluated as potential candidates for the solvent-based amine capture system: MEA, concentrated piperazine, and Shell's Cansolv solvent. While MEA is the most studied solvent with a published, transparent data set for CO_2 capture, the MEA solvent was not selected because it is a first-generation amine solvent with a higher reboiler duty; it is less likely to be competitive in a net-zero grid framework. Concentrated piperazine had the lowest reboiler duty of the three solvents considered, but there was no open-source model available for piperazine and limited cost data. The Shell Cansolv system has a significantly lower reboiler duty than MEA (though somewhat higher than piperazine); while it is a proprietary solvent, there are publicly available cost models for the Cansolv system. Therefore, Cansolv was selected as the solvent basis for the amine capture system.

- *CO_2 capture rate selection.* A CO_2 capture rate of 97% was selected for the amine system. A capture rate of 90% capture had previously been the baseline capture rate for many carbon capture studies (including [5]), but the baseline level of capture of interest has recently shifted to 95% and beyond. At the time of this study, the DOE has not yet published data for these higher levels of CO_2 capture for the Cansolv system. Based on published data for MEA and piperazine, the reboiler duty (on a GJ/tonne CO_2 basis) for these solvents is relatively flat from 90% capture up to 95% capture, while reboiler duty is much higher at 99% capture [1, 10]. There are few published data on reboiler duty between 95 and 99% capture; however, based on conversations with industry colleagues, the team anticipates that 97% CO_2 capture might be achieved without significant penalty in reboiler duty (on a GJ/tonne or MMBtu/tonne CO_2 basis). Therefore, for this project, the design was made to target 97% CO_2 capture with the amine system, with the preliminary assumption that reboiler duty on a GJ/tonne CO_2 basis will be the same as at 90% CO_2 capture.
- *Amount of flue gas treated.* For this project, 100% of the flue gas from the HRSG will be treated by the PCC at all NGCC operating loads, with the exception of start-up (discussed in Section 6.2). The flue gas flowrate varies with ambient temperature, with more flue gas generated at lower ambient temperatures and less flue gas generated at higher ambient temperatures. To treat 100% of the flue gas over the range of flue gas flowrates, a leak-tight damper may be needed on the HRSG stack. This damper would prevent flue gas from short-circuiting the carbon capture system to exit via the HRSG stack, and it would prevent air ingress via the stack. Such a damper would need to be fast-acting to open in case of a shutdown of the carbon capture units (e.g., flue gas fan fails) so that back-pressure does not build on the HRSG. Other engineering solutions beside such a damper may be possible; the appropriate solution is beyond the scope of this current study and would need to be explored as the process concept progresses to a more detailed design phase.
- *Design for flexibility.* The NGCC operating scenarios that set the limits for the maximum and minimum CO_2 processing rates by the PCC are:
  - 2 gas turbines x 100% load, which sets the maximum CO_2 rate to the PCC unit, 250 tonne CO_2/h.
  - 1 gas turbine x 50% load, which sets the minimum CO_2 rate to the PCC unit, 78 tonne CO_2/h. The turndown required from maximum PCC CO_2 rate is 31%.

Many of the recent DOE-funded FEED studies completed for NGCC units include two amine absorbers due to the large volume of flue gas to be treated. Absorption columns typically achieve 50% turndown, and thus two columns would achieve the required turndown of 31%. If needed, single absorber columns can be designed for lower turndown (∼33%) via design of the liquid distributors.

2.2. PCC Compressor Design

The primary design decisions for the PCC compression were related to enabling flexible operation of the compression system. Flexible operation includes being able to operate the compressors between the minimum and maximum CO_2 flowrates and being able to start and stop the compression system when the NGCC is taken offline and brought online.

The NGCC operating limits for the maximum and minimum CO_2 processing rates by the PCC Compressor are 250 tonne CO_2/h and 78 tonne CO_2/h as stated above. The project team made the following decisions with respect to the design of the PCC Compression system:

- *Achieving required turndown for PCC CO_2 processing.* The limiting factor in the turndown of the PCC unit is associated with the PCC CO_2 compressor. The TEG dehydration can achieve 25% turndown on the gas side, but the turndown of the compressors is nominally 75% for integrally-geared compressors. Case B31B in [5] includes two parallel integrally-geared compressor trains, which would offer overall system turndown to approximately 38%. To achieve the required turndown of 31% required for the very lowest gas turbine loads, CO_2 must be recycled to the front end of the compressor to maintain volumetric flow through the compressor. This recycle stream increases the power requirement of the compressor. When the NGCC is operating in the max DAC condition, power prices are expected to be low, so some increased auxiliary load due to CO_2 recycling might be tolerated. The electricity consumption values for PCC compression included a recycle penalty for the integrally-geared compressors for low operating loads.
- *Enabling multiple starts/stops for PCC CO_2 processing.* The team talked with two compressor vendors about designing centrifugal and reciprocating compression equipment for multiple starts and stops. One vendor indicated that a typical compressor might be designed for 1,000 starts over a 20-year design life. Large-scale industrial plants can operate for one to seven years without maintenance shutdowns, so compressor equipment is often typically designed for long continuous run-times without maintenance. Both vendors indicated that the compressors could be readily designed for many starts and stops; since these large compressors are custom engineered products, the compressor can be engineered for parts to have the appropriate thicknesses and materials of construction to accommodate the stress associated with many starts and stops. In addition, variable frequency drives (VFDs) can be added to the compressor to slow the start-up process and further reduce mechanical stresses. The vendors indicated that VFDs are becoming more common to mitigate grid brownouts that can occur when large compressors come online. One vendor indicated that adding 15% to the capital cost of the compressor and motor would be a first approximation to cover the cost of a VFD and additional engineering of materials; the cost for one VFD per compressor was incorporated into the system cost model. A single VFD can start-up multiple motors, if ratings are compatible and the start-up can be staged.

The final utility data for the PCC unit and the compressors is given in Table 8. A rough eqiupment list is given in Table 9.

Table 8: Utility data for PCC

utility data	unit	value
maximum CO_2 capture rate	%	97
steam requirement for PCC	MMBTU/tonne CO_2	2.71
power requirement for PCC	MWh/tonne CO_2	0.047
	m	b
if load% $\in [37.5, 100]$	0	0.076
if load% $\in [0, 37.5]$	-0.2239	0.1479

Table 9: Equipment list for PCC

equip type	equip name	MOC	design parameter	commercially available	commercial notes
CO_2 capture system	PCC	stainless steel	CO_2 flowrate	Yes	Cansolv process
CO_2 processing unit	PCC compression and dehydration	carbon steel and stainless steel	CO_2 flowrate	Yes	integrally geared centrifugal compressor with TEG dehydration
CO_2 processing unit	DAC compression and purification	carbon steel and stainless steel	CO_2 flowrate	Yes	liquefaction/distillation process for CO_2 purification

3. DAC & DAC Purification and Compression Design

3.1. DAC Design

The DAC process block consists of the DAC sorbent beds which alternate operation between absorption and regeneration modes, a condenser and knockout drum to process the CO_2 leaving the regenerator, and a deaerator to remove dissolved gases (CO_2, air) from the condensed water that is returned to the DAC steam cycle. The block flow diagram (Figure 14 in Section 4) shows the vent stream from the deaerator being recycled to the PCC to recover the CO_2 in the vent stream; however, at 2 × 100% load, "max DAC" conditions, the CO_2 in this stream is very small (221 kg/h) compared to the CO_2 captured in the DAC (134,000 kg/h). The cost of the PCC system does not include the ductwork to convey this CO_2 to the PCC. The cost of the ductwork to convey the deaerator vent CO_2 to the PCC is dependent upon the relative layouts of the DAC and PCC and could be quite significant. This level of design detail and costing was beyond the scope of this project.

3.2. DAC Purification and Compression Design

The DAC CO_2 contains significant levels of oxygen which would need to be removed to meet a 10 ppm O_2 specification of a typical CO_2 pipeline; selection of the CO_2 product specification is discussed in the following paragraphs. The DAC purification and compression system is based upon the liquefaction/distillation process for removing inerts from the DAC CO_2.

A BFD and associated stream tables for the DAC purification and compression system is provided in Figure 14 and Table 17. The process steps associated with liquefaction/distillation for processing CO_2 with off-spec inerts include compression, dehydration, condensation (liquefaction), distillation, and pumping to pipeline pressure.

Liquefaction/distillation is used commercially to produce food and beverage grade CO_2. A more detailed example process flow diagram and process description can be found in the section "Food and Beverage Grade Cases" on pages 5 through 11 of [9]. Process flow diagrams are shown in Figures 3–5 of [9]. A summary process description is as follows:

- An inlet blower compresses the CO_2 from near atmospheric pressure up to about 2 bar. The hot compressed gas is cooled and condensed water is removed.
- The CO_2 is further compressed in an oil-flooded screw compressor to the liquefaction pressure. The liquefaction design pressure is determined by an optimization of the power requirements for the refrigeration system, pumping energy, and capital costs. The hot compressed CO_2 is cooled in a water-cooled aftercooler to reduce gas temperature and condense water out of the gas stream. A refrigerant cooled exchanger further cools the gas stream to condense as much water out of the gas as possible. The gas is then superheated to prevent any liquid condensation in the downstream dryer beds.
- Prior to liquefying the CO_2, water is removed to very low concentrations to prevent formation of ice and hydrates at the low temperatures used for CO_2 liquefaction. Mole sieve dehydration is typical for CO_2 liquefaction, but other desiccants could be used depending on considerations of replacement frequency and operating costs. The regeneration gas for the dehydration beds flows back to the suction of the CO_2 compressor to minimize CO_2 losses in the system.
- The dehydrated CO_2 flows into a reboiler where liquid CO_2 from the distillation bottoms cools the gaseous CO_2 to near the liquefaction temperature. The cold dry CO_2 flows into the main condenser where the CO_2 is liquefied by exchanging heat with evaporating refrigerant.
- The liquid CO_2 is fed to the top of a distillation tower and flows counter-currently to rising hot vapor that strips inerts (such as O_2 and N_2) out of the liquid CO_2. Near-pure CO_2 collects in the bottom of the distillation column. The liquid CO_2 bottoms are pumped to pipeline pressure.
- A refrigerated vent condenser (CO_2 reflux) may be used to increase the yield of liquid CO_2 product. While the distillation column includes an overhead condenser to decrease CO_2 losses from the CO_2 overheads, this stream still contains approximately 60 wt% CO_2. The BFD (Figure 14) shows the overhead vent stream from the distillation column recycled to the PCC unit; the CO_2 in this stream (4,260 kg/h) is small compared to the PCC processing rate (250,000 kg/h). The cost of the PCC system does not include the ductwork to convey this overhead vent CO_2 to the PCC. The cost of this ductwork could be significant, depending upon the layout of the DAC system

with respect to the PCC. Other options might be possible for recovering this CO_2 vent, such as CO_2-selective membranes.

The project team made the following decisions with respect to the design of the DAC purification and compression system:

- *CO_2 product specification.* The U.S. DOE NETL publishes Quality Guidelines for Energy Systems Studies [11] that includes a review of CO_2 product specifications. The CO_2 product specification depends upon whether the CO_2 will be transported through commercial carbon steel pipeline, used for enhanced oil recovery, and/or sequestered in a saline reservoir. For this project, the relevant species of interest and their conceptual design values in [11] include: CO_2 ($>$ 95 mol%), H_2O ($<$ 500 ppmv), N_2 and Ar ($<$ 1 to 4 mol%, depending on CO_2 disposition), and O_2 ($<$ 10 ppmv). For each of these species, [11] also provides a range of specification values that can be found in literature. The concentrations of inerts such as N_2 and Ar are typically capped to reduce the volumetric flowrate of the CO_2 stream and thus reduce the power required to compress the CO_2 stream and reduce the mass of inerts in the storage formation. Limits on O_2 in the CO_2 product are driven by concerns about the reactivity of O_2 in the geological formation.
- *Oxygen specification for CO_2 product.* The CO_2 streams produced by the DAC unit will contain oxygen as an impurity at concentrations of 4,000–5,000 ppmv, which exceeds the conceptual design values in [11]. However, in practice, there is no single technical standard for O_2 in CO_2 that is geologically sequestered. The team's experience has been that uncertainty about subsurface impacts and varying risk tolerance among project developers can lead to a wide range of O_2 limit specifications between projects. Use of liquefaction and distillation to meet an O_2 specification can significantly increase the electricity and purchased equipment costs of the purification system. For this project, the team decided to design to use a limit of 10 ppmv O_2 in the CO_2, which aligns with [11] and the specification for CO_2 entering a common carrier pipeline. If the project were to have a project-dedicated pipeline and the sequestration chemistry were favorable, higher O_2 limits than 10 ppmv might be theoretically supported.
- *Technology for inerts removal.* CO_2 that carries off-specification concentrations of inerts (O_2, N_2) is typically processed by liquefaction and distillation. The team has designed several commercial-scale liquefaction and distillation units for the food and beverage grade industry. There are potentially other technology options for inerts removal from the CO_2, such as a catalytic process to remove O_2; the team has not found published performance data for these alternate approaches that supports their commercial availability for this application. Therefore, for this project, a liquefaction/distillation process was proposed.
- *Flexibility.* For the DAC unit, the operating scenarios of interest are:
  - 2 gas turbines x 100% load, "max DAC", which sets the maximum CO_2 rate to the DAC system, 138 tonne CO_2/h.
  - 2 gas turbine x 100% load, "min DAC", which sets the minimum CO_2 flow rate

to the DAC system, 33 tonne CO_2/h. The turndown required from maximum DAC CO_2 rate is 24%.

The DAC compression and purification system is designed to achieve the required turndown of 24%. The system has multiple screw compressors, each of which can achieve 10% turndown; two distillation columns, each of which can achieve 50% turndown–one distillation column can be taken out of service to meet lower turndowns; and multiple molecular sieve trains and multiple refrigerant compressor trains, which can also achieve the required turndown.

- Based on these, the power requirement for the DAC compressor is determined to be 0.138 MWh/tonne CO_2.

A rough equipment list for the DAC processing unit is given in Table 10.

Table 10: Equipment list for DAC processing

equip type	equip name	MOC	design parameter	commercially available	commercial notes
CO_2 processing unit	DAC compression and purification	carbon steel and stainless steel	CO_2 flowrate	Yes	liquefaction/distillation process for CO_2 purification

4. System Overview and Performance

4.1. System Performance in "Min DAC" and "Max DAC" Modes

Performance of the NGCC in the "min DAC" mode is given in Table 11. Performance of the NGCC in the "max DAC" mode is given in Table 12.

For the "min DAC" case, notice that the CO_2 emissions from the combined plant (NGCC, PCC, and DAC) are negative across all loads. There is a decrease in efficiency compared to the non-carbon capture cases shown in Table 7 due to the loss of power from the LP turbine. However, the overall plant efficiency is comparable to an ultra-supercritical coal fired boiler.

The "max DAC" cases all have significantly negative CO_2 emissions across all loads due to the increased CO_2 removal in the DAC system. However, for these cases there is no LP turbine power so the overall plant efficiency decreases. Even with the decrease in power to remove additional CO_2, the overall plant efficiency is comparable to a sub-critical coal plant.

Table 11: NGCC Retrofit performance in "min DAC" mode

total load factor Configuration		100% 2 × 100%	90% 2 × 90%	80% 2 × 80%	70% 2 × 70%	60% 2 × 60%	50% 2 × 50%	50% 1 × 100%	40% 1 × 80%	30% 1 × 60%	25% 1 × 50%
gas turbine	kW	477,000	429,300	381,600	333,900	286,200	238,500	238,500	190,800	143,100	119,250
steam turbine	kW	165,761	157,988	148,015	135,917	125,149	107,713	75,594	67,333	57,073	49,203
HP	kW	52,010	49,180	45,400	41,573	37,846	32,601	23,432	20,653	17,190	14,609
IP	kW	48,755	44,728	41,032	36,709	32,245	25,511	23,864	19,944	15,665	13,402
LP	kW	64,996	64,080	61,583	57,635	55,058	49,601	28,298	26,736	24,218	21,192
total gross power	kW	642,761	587,288	529,615	469,817	411,349	346,213	314,094	258,133	200,173	168,453
circulating water pumps	kW	4,759	4,504	4,215	3,891	3,571	3,210	2,451	2,182	1,856	1,660
combustion turbine auxiliaries	kW	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
condensate pumps	kW	177	168	158	147	136	123	89	79	68	61
cooling tower fans	kW	2,472	2,340	2,190	2,022	1,855	1,668	1,274	1,134	964	863
feedwater pumps	kW	5,440	5,046	4,538	4,024	3,554	2,908	1,898	1,632	1,318	1,107
ground water pumps	kW	469	444	415	383	352	316	242	215	183	163
miscellaneous balance of plant	kW	570	570	570	570	570	570	570	570	570	570
scr	kW	2	2	2	2	2	2	2	2	2	2
steam turbine auxiliaries	kW	200	200	200	200	200	200	200	200	200	200
transformer losses	kW	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250
PCC power	kW	11,774	10,971	10,166	9,249	8,317	7,303	5,887	5,083	4,158	3,652
PCC compression power	kW	19,039	17,740	16,439	14,956	13,448	11,810	9,519	8,219	7,140	7,140
DAC power	kW	8,571	8,150	7,652	7,094	6,531	5,718	4,494	4,007	3,398	2,903
DAC compression power	kW	4,731	4,499	4,224	3,916	3,605	3,156	2,481	2,212	1,876	1,603
total auxiliaries	kW	61,474	57,904	54,040	49,724	45,410	40,253	32,377	28,805	25,003	23,194
net power	kW	581,287	529,384	475,575	420,093	365,939	305,960	281,717	229,328	175,170	145,259
natural gas flow	lb/h	205,630	191,585	177,541	161,502	145,195	127,388	102,815	88,770	72,598	63,694
	kg/h	93,356	86,980	80,604	73,322	65,919	57,834	46,678	40,302	32,959	28,917
heat input to turbine(s)	MMBTU/h	4,616	4,300	3,985	3,625	3,259	2,859	2,308	1,993	1,630	1,430
	GJ/h	4,869	4,537	4,204	3,824	3,438	3,017	2,435	2,102	1,719	1,508
HHV net plant heat rate	BTU/kWh	7,940	8,123	8,380	8,629	8,906	9,346	8,192	8,689	9,303	9,842
	kJ/kWh	8,377	8,570	8,840	9,104	9,396	9,860	8,642	9,166	9,814	10,384
HHV net plant efficiency	%	43.0%	42.0%	40.7%	39.5%	38.3%	36.5%	41.6%	39.3%	36.7%	34.7%
CO_2 emission rate	tonne CO_2/MWh	-0.046	-0.048	-0.050	-0.053	-0.056	-0.059	-0.050	-0.055	-0.062	-0.063

Table 12: NGCC Retrofit performance in “max DAC” mode

total load factor		100%	90%	80%	70%	60%	50%	50%	40%	30%	25%
Configuration		2 × 100%	2 × 90%	2 × 80%	2 × 70%	2 × 60%	2 × 50%	1 × 100%	1 × 80%	1 × 60%	1 × 50%
gas turbine	kW	477,000	429,300	381,600	333,900	286,200	238,500	238,500	190,800	143,100	119,250
steam turbine	kW	100,765	93,908	86,432	78,282	70,091	58,112	47,296	40,597	32,855	28,011
HP	kW	52,010	49,180	45,400	41,573	37,846	32,601	23,432	20,653	17,190	14,609
IP	kW	48,755	44,728	41,032	36,709	32,245	25,511	23,864	19,944	15,665	13,402
LP	kW	-	-	-	-	-	-	-	-	-	-
total gross power	kW	577,765	523,208	468,032	412,182	356,291	296,612	285,796	231,397	175,955	147,261
circulating water pumps	kW	4,536	4,286	4,002	3,686	3,372	3,007	2,291	2,025	1,710	1,516
combustion turbine auxiliaries	kW	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
condensate pumps	kW	178	170	159	148	137	123	89	80	69	62
cooling tower fans	kW	2,357	2,227	2,079	1,915	1,752	1,562	1,190	1,052	889	788
feedwater pumps	kW	5,434	5,044	4,540	4,026	3,554	2,908	1,898	1,633	1,318	1,107
ground water pumps	kW	517	491	460	426	392	351	261	232	198	176
miscellaneous balance of plant	kW	570	570	570	570	570	570	570	570	570	570
scr	kW	2	2	2	2	2	2	2	2	2	2
steam turbine auxiliaries	kW	200	200	200	200	200	200	200	200	200	200
transformer losses	kW	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250
pcc power	kW	11,774	10,971	10,166	9,249	8,317	7,303	5,887	5,083	4,158	3,652
pcc compression power	kW	19,039	17,740	16,439	14,956	13,448	11,810	9,519	8,219	7,140	7,140
dac power	kW	35,088	34,235	32,489	30,735	29,129	26,666	17,524	16,300	14,576	13,019
dac compression power	kW	19,368	18,898	17,934	16,966	16,079	14,720	9,673	8,997	8,046	7,186
total auxiliaries	kW	102,333	98,104	92,310	86,149	80,221	72,493	52,374	47,664	42,146	38,688
net power	kW	475,432	425,104	375,722	326,033	276,070	224,119	233,422	183,733	133,809	108,573
natural gas flow	lb/h	205,630	191,585	177,541	161,502	145,195	127,388	102,815	88,770	72,598	63,694
	kg/h	93,356	86,980	80,604	73,322	65,919	57,834	46,678	40,302	32,959	28,917
heat input to turbine(s)	MMBTU/h	4,616	4,300	3,985	3,625	3,259	2,859	2,308	1,993	1,630	1,430
	GJ/h	4,869	4,537	4,204	3,824	3,438	3,017	2,435	2,102	1,719	1,508
HHV net plant heat rate	BTU/kWh	9,708	10,116	10,606	11,119	11,805	12,758	9,887	10,845	12,178	13,168
	kJ/kWh	10,242	10,672	11,190	11,730	12,454	13,460	10,431	11,441	12,848	13,892
HHV net plant efficiency	%	35.1%	33.7%	32.2%	30.7%	28.9%	26.7%	34.5%	31.5%	28.0%	25.9%
CO_2 emission rate	tonne CO_2/MWh	-0.279	-0.305	-0.328	-0.358	-0.402	-0.455	-0.284	-0.337	-0.415	-0.458

4.2. Process Flow Diagram & Heat and Material Balance

The HRSG PFD is shown in Figure 1 in Section 1. The PFD for the steam cycle in both modes are shown in Figures 12–13. The colored version for the steam cycle PFD is also shown in Figuers 7–9 in Section 1. The block flow diagram for the PCC and DAC units is presented in Figure 14.

The heat and material balance (HMB) tables for NGCC stream are given in Tables 13–16 Finally, the HMB for DAC and PCC are presented in 17.

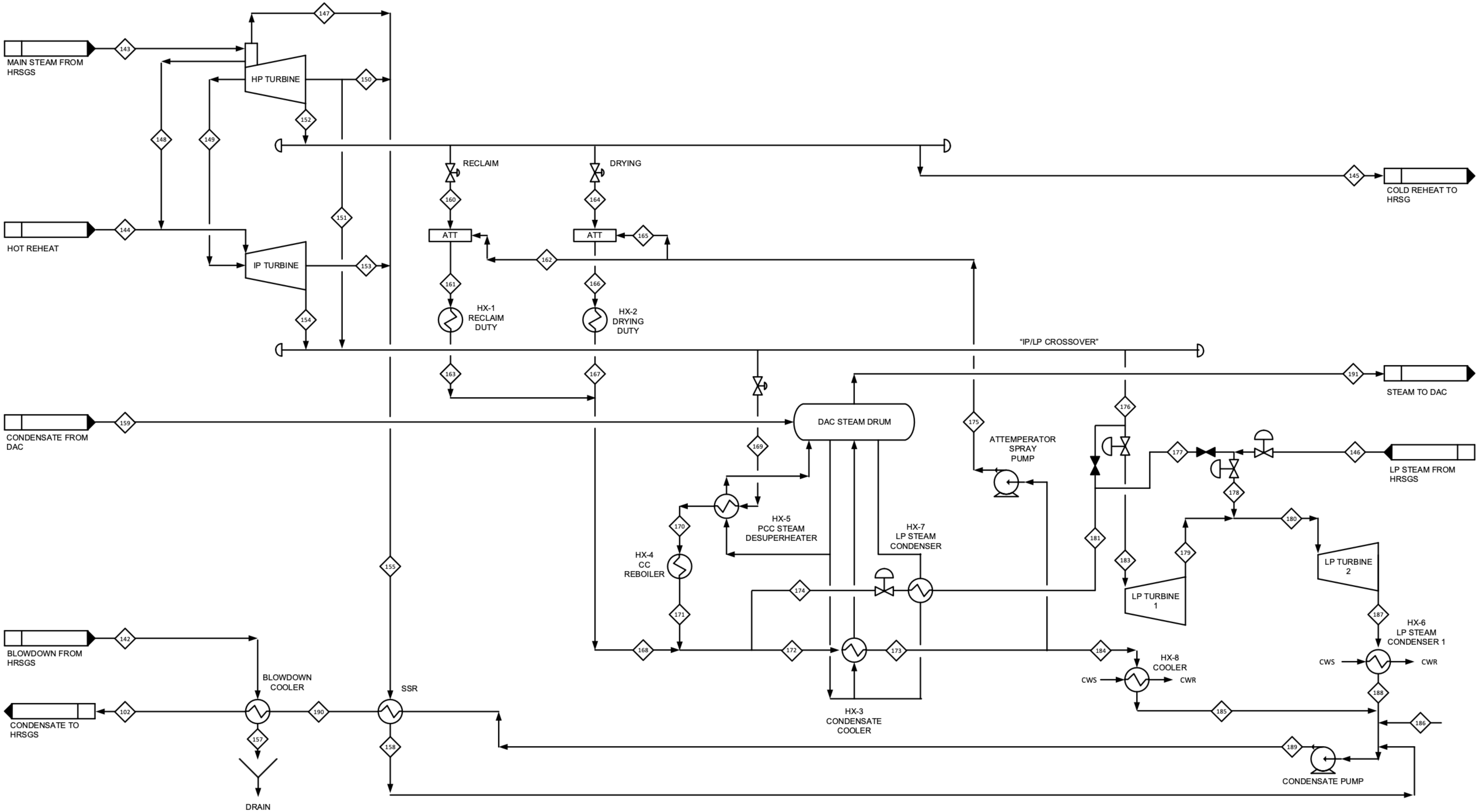

Figure 12: Process flow diagram for “min DAC” mode

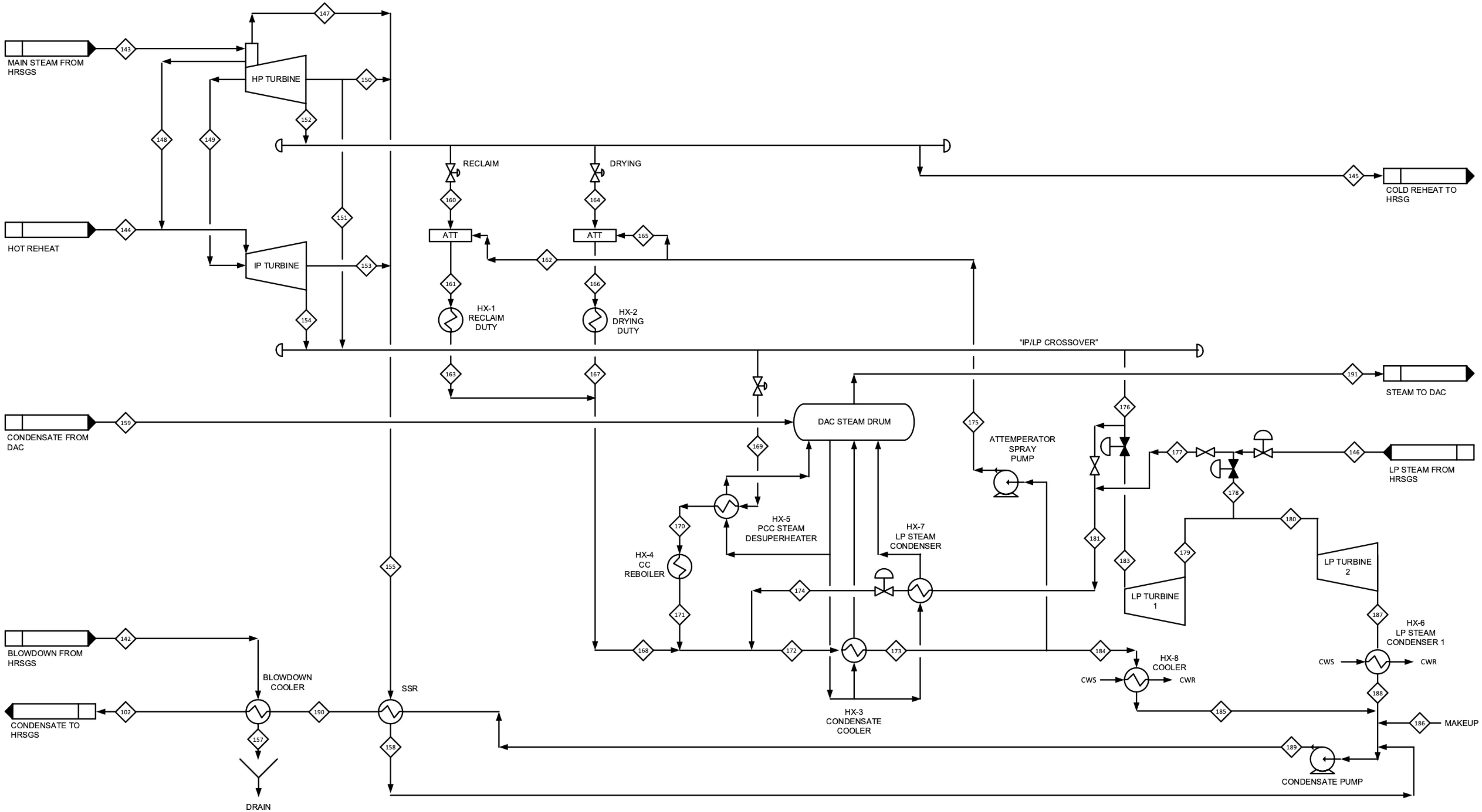

Figure 13: Process flow diagram for "max DAC" mode

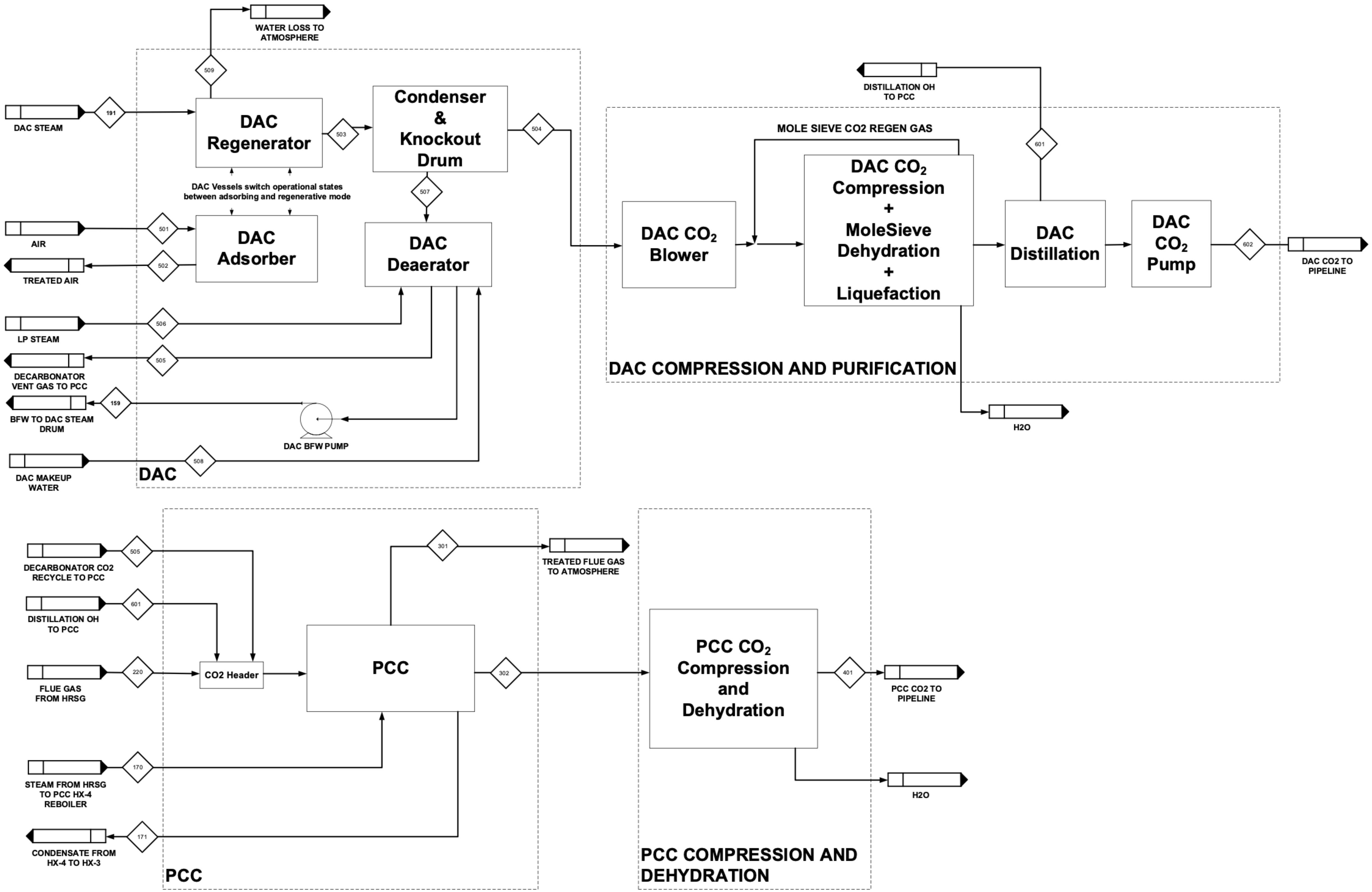

Figure 14: Block flow diagram for the PCC and DAC units

Table 13: Stream tables for NGCC, min DAC, streams and water streams

	stream number		102	103	104	105	106	107	108/108A	109	110	111/111A	112	113/113A	114/114A	115	116	117	118	119	120	121
	description		total condensate to both HRSGs	condensate to one HRSG	condensate entering the LP evaporator	condensate from LP evaporator to pumps	LP steam from evaporator	HP BFW from pump To HP Econ 1	spray water for main steam DSH	HP BFW from HP Econ 1 to HP Econ 2	IP BFW from pump to IP Econ 1	spray water for reheat DSH	IP BFW from IP Econ 1 to IP Econ 2	hot BFW supply to NG preheater	BFW return from NG preheater	IP BFW entering the IP evaporator	HP BFW from HP Econ 2 to HP Econ 3	IP steam from evaporator	HP BFW from HP Econ 3 to HP Econ 4	HP BFW from HP Econ 4 To HP Econ 5	HP BFW entering the HP evaporator	IP steam exiting IP SH1
load	phase		liquid	liquid	liquid	liquid	vapor	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid	liquid	vapor	liquid	liquid	liquid	vapor
100% (2 × 100%)	mass flow	kg/h	621,999	310,999	340,415	305,203	34,194	231,753	0	231,753	73,449	0	44,033	58,832	58,832	44,033	231,753	43,813	231,753	231,753	231,753	43,813
	temperature	°C	44.7	44.7	152.7	154.8	154.8	160.6	160.6	218.5	155.7	155.7	216.9	216.9	60.0	242.3	242.9	244.8	316.0	327.1	355.1	335.8
	pressure	bar	6.00	6.00	5.70	5.41	5.41	235.90	235.90	228.04	40.71	40.71	39.26	39.26	40.33	37.81	220.18	36.37	212.32	204.46	196.60	34.92
	enthalpy	kJ/kg	187.7	187.7	644.0	653.0	2,751.6	691.9	691.9	943.6	659.0	658.9	930.0	930.0	254.5	1,048.8	1,054.1	2,802.4	1,420.4	1,486.8	1,693.1	3,070.2
90% (2 × 90%)	mass flow	kg/h	591,004	295,502	326,329	292,574	32,779	214,930	6,476	214,930	70,097	1,070	42,691	54,813	54,813	42,691	214,930	42,264	214,930	214,930	214,930	42,264
	temperature	°C	44.9	44.9	152.1	154.8	154.8	160.4	160.4	217.8	155.7	155.7	215.8	215.8	60.0	240.1	241.2	242.4	315.3	326.0	353.1	333.8
	pressure	bar	6.00	6.00	5.70	5.41	5.41	228.88	228.88	221.02	39.27	39.27	37.82	37.82	40.33	36.37	213.16	34.92	205.30	197.44	189.58	33.47
	enthalpy	kJ/kg	188.4	188.4	641.2	653.0	2,751.6	690.7	690.7	940.0	658.8	658.7	925.0	925.0	254.5	1,038.2	1,045.8	2,802.8	1,417.3	1,481.5	1,680.1	3,069.1
80% (2 × 80%)	mass flow	kg/h	555,951	277,975	310,469	279,751	29,789	184,169	22,278	184,169	67,343	5,960	41,945	50,796	50,796	41,945	184,169	41,526	184,169	184,169	184,169	41,526
	temperature	°C	44.9	44.9	151.0	154.8	154.8	160.2	160.2	218.3	155.6	155.6	214.4	214.4	60.0	237.3	240.1	239.5	316.8	326.4	351.0	331.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	219.55	219.55	211.69	37.51	37.51	36.06	36.06	40.33	34.62	203.83	33.17	195.97	188.11	180.25	31.72
	enthalpy	kJ/kg	188.4	188.4	636.4	653.0	2,751.6	689.1	689.1	942.0	658.5	658.4	918.5	918.5	254.5	1,024.7	1,040.5	2,803.1	1,427.5	1,485.9	1,667.8	3,066.9
70% (2 × 70%)	mass flow	kg/h	516,048	258,024	287,612	259,731	27,021	165,822	25,463	165,822	62,989	5,457	39,886	46,207	46,207	39,886	165,822	39,487	165,822	165,822	165,822	39,487
	temperature	°C	45.0	45.0	150.9	154.8	154.8	159.9	159.9	216.9	155.6	155.6	212.9	212.9	60.0	234.3	237.3	236.0	315.6	324.5	347.7	328.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	209.98	209.98	202.12	35.53	35.53	34.08	34.08	40.33	32.63	194.26	31.19	186.40	178.54	170.68	29.74
	enthalpy	kJ/kg	189.1	189.1	636.3	653.0	2,751.6	687.5	687.5	935.4	658.2	658.1	911.4	911.4	254.5	1,010.6	1,027.7	2,803.3	1,421.5	1,475.9	1,645.0	3,064.8
60% (2 × 60%)	mass flow	kg/h	477,048	238,524	264,962	239,867	24,302	149,036	27,735	149,036	58,362	4,734	37,591	41,541	41,541	37,591	149,036	37,215	149,036	149,036	149,036	37,215
	temperature	°C	45.3	45.3	150.9	154.8	154.8	159.7	159.7	215.2	155.5	155.5	211.3	211.3	60.0	231.4	234.5	232.4	313.8	322.2	344.1	325.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	200.64	200.64	192.78	33.58	33.58	32.13	32.13	40.33	30.68	184.92	29.23	177.06	169.20	161.34	27.79
	enthalpy	kJ/kg	190.1	190.1	636.3	653.0	2,751.6	686.0	685.9	927.4	657.8	657.7	903.9	903.9	254.5	996.8	1,014.5	2,803.2	1,412.8	1,463.4	1,619.9	3,062.5
50% (1 × 100%)	mass flow	kg/h	310,924	310,924	340,421	316,442	22,960	221,308	18,069	221,308	76,984	82	47,568	29,416	29,416	47,568	221,308	47,330	221,308	221,308	221,308	47,330
	temperature	°C	46.7	46.7	150.8	154.8	154.8	158.8	158.8	201.3	155.3	155.3	198.4	198.4	60.0	216.5	218.4	215.3	292.1	302.2	326.6	308.1
	pressure	bar	6.00	6.00	5.70	5.41	5.41	163.36	163.36	155.50	25.52	25.52	24.08	24.08	40.33	22.63	147.64	21.18	139.78	131.92	124.06	19.73
	enthalpy	kJ/kg	195.9	195.9	635.6	653.0	2,751.6	679.7	679.6	864.2	656.5	656.4	845.7	845.7	254.5	927.6	940.3	2,799.5	1,296.3	1,352.3	1,502.9	3,043.7
40% (1 × 80%)	mass flow	kg/h	278,969	278,969	310,315	289,960	19,426	182,135	34,274	182,135	68,731	4,821	43,333	25,398	25,398	43,333	182,135	42,900	182,135	182,135	182,135	42,900
	temperature	°C	46.9	46.9	149.2	154.8	154.8	158.6	158.6	199.9	155.3	155.3	196.5	196.5	60.0	212.8	215.2	211.2	291.3	300.3	321.8	304.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	155.22	155.22	147.36	23.87	23.87	22.42	22.42	40.33	20.97	139.50	19.52	131.64	123.78	115.92	18.07
	enthalpy	kJ/kg	196.8	196.8	628.8	653.0	2,751.6	678.3	678.3	857.5	656.2	656.1	837.1	837.1	254.5	910.6	925.5	2,797.9	1,292.7	1,342.2	1,473.1	3,039.2
30% (1 × 60%)	mass flow	kg/h	239,741	239,741	264,946	248,866	15,288	152,173	34,936	152,173	58,271	3,486	37,500	20,770	20,770	37,500	152,173	37,125	152,173	152,173	152,173	37,125
	temperature	°C	47.3	47.3	149.3	154.8	154.8	158.3	158.3	196.4	155.2	155.2	193.9	193.9	60.0	208.1	210.1	205.7	287.3	295.4	315.0	299.0
	pressure	bar	6.00	6.00	5.70	5.41	5.41	145.24	145.24	137.38	21.82	21.82	20.37	20.37	40.33	18.92	129.52	17.48	121.66	113.80	105.94	16.03
	enthalpy	kJ/kg	198.7	198.7	629.4	653.0	2,751.6	676.6	676.6	841.8	655.9	655.8	825.2	825.2	254.5	889.0	902.4	2,795.2	1,272.0	1,316.2	1,431.1	3,033.1
25% (1 × 50%)	mass flow	kg/h	215,494	215,494	231,781	216,329	14,758	167,008	0	167,008	49,321	0	34,039	15,282	15,282	34,039	167,008	33,699	167,008	167,008	167,008	33,699
	temperature	°C	47.7	47.7	152.7	154.8	154.8	158.1	158.1	191.5	155.2	155.2	192.3	192.3	60.0	204.5	204.6	201.1	277.4	286.9	308.9	294.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	137.37	137.37	129.51	20.25	20.25	18.80	18.80	40.33	17.35	121.65	15.90	113.79	105.93	98.07	14.45
	enthalpy	kJ/kg	200.4	200.4	643.8	653.0	2,751.6	675.3	675.2	819.7	655.6	655.5	818.2	818.2	254.5	872.6	877.1	2,792.7	1,221.0	1,270.6	1,395.0	3,026.9

Table 13: Stream tables for NGCC, min DAC, streams and water streams (continued)

	stream number		**122**	**123**	**124**	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**	**138**	**139**	**140**	**141**
	description		**HP steam from evaporator**	**HP steam from HP SH 1 to HP SH 2**	**combined cold reheat steam plus IP steam from HRSG**	**IP steam from IP SH 2/RH 1 to RH DSH**	**IP steam from RH DSH to IP SH 3/RH 2**	**HP steam from HP SH 2 to MS DSH**	**HP steam from MS DSH to HP SH 3**	**HP steam from HP SH 3 tO HP SH 4**	**main steam from one HRSG**	**cold reheat to one HRSG**	**hot reheat from one HRSG**	**LP steam from one HRSG**	**HP pump suction**	**IP pump suction**	**HP pump discharge**	**IP pump discharge**	**deaerator vent**	**combined flow exiting IP Econ 1**	**IP evaporator blowdown**	**HP evaporator blowdown**
load	phase		**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**
100% (2 × 100%)	mass flow	kg/h	230,595	230,595	261,856	261,856	261,856	230,595	230,595	230,595	230,595	218,043	261,856	34,194	231,753	132,281	231,753	132,281	1,018	73,449	220	1,159
	temperature	°C	360.9	408.3	352.0	475.8	475.8	454.6	454.6	519.7	584.8	355.3	584.3	281.4	154.8	154.8	160.6	155.7	154.8	216.9	244.8	360.9
	pressure	bar	188.74	180.88	34.92	33.47	33.47	173.02	173.02	165.16	157.30	34.92	32.02	5.11	5.41	5.41	235.90	40.71	5.41	39.26	36.37	188.74
	enthalpy	kJ/kg	2,471.4	2,925.7	3,109.9	3,398.4	3,398.4	3,131.3	3,131.3	3,348.4	3,536.6	3,117.8	3,645.5	3,026.0	653.0	653.0	691.9	658.9	2,751.6	930.0	1,060.4	1,771.0
90% (2 × 90%)	mass flow	kg/h	212,781	212,781	249,589	249,589	250,659	212,781	219,257	219,257	219,257	207,326	250,659	32,779	221,406	129,999	221,406	129,999	976	70,097	213	1,075
	temperature	°C	357.8	412.4	353.8	475.5	470.3	460.2	439.3	512.3	585.1	358.0	584.6	280.1	154.8	154.8	160.4	155.7	154.8	215.8	242.4	357.8
	pressure	bar	181.72	173.86	33.47	32.03	32.03	166.00	166.00	158.14	150.28	33.47	30.58	5.11	5.41	5.41	228.88	39.27	5.41	37.82	34.92	181.72
	enthalpy	kJ/kg	2,502.5	2,964.2	3,117.5	3,399.6	3,387.9	3,163.4	3,090.3	3,335.9	3,543.9	3,127.4	3,647.3	3,023.1	653.0	653.0	690.7	658.7	2,751.6	925.0	1,049.2	1,739.5
80% (2 × 80%)	mass flow	kg/h	182,328	182,328	234,971	234,971	240,931	182,328	204,606	204,606	204,606	193,445	240,931	29,789	206,448	132,135	206,448	132,135	929	67,343	210	921
	temperature	°C	353.4	416.2	356.3	469.3	439.3	463.7	391.5	481.3	585.0	361.8	584.5	281.4	154.8	154.8	160.2	155.6	154.8	214.4	239.5	353.4
	pressure	bar	172.39	164.53	31.72	30.27	30.27	156.67	156.67	148.81	140.95	31.72	28.82	5.11	5.41	5.41	219.55	37.51	5.41	36.06	33.17	172.39
	enthalpy	kJ/kg	2,538.8	3,004.7	3,127.2	3,387.6	3,320.1	3,190.6	2,918.2	3,257.5	3,552.1	3,140.1	3,648.6	3,025.8	653.0	653.0	689.1	658.4	2,751.6	918.5	1,035.1	1,699.9
70% (2 × 70%)	mass flow	kg/h	164,164	164,164	218,766	218,766	224,222	164,164	189,627	189,627	189,627	179,278	224,222	27,021	191,285	127,278	191,285	127,278	860	62,989	199	829
	temperature	°C	348.8	421.1	359.0	469.4	439.7	468.9	377.5	474.5	585.0	365.9	584.5	280.5	154.8	154.8	159.9	155.6	154.8	212.9	236.0	348.8
	pressure	bar	162.82	154.96	29.74	28.29	28.29	147.10	147.10	139.24	131.38	29.74	26.84	5.11	5.41	5.41	209.98	35.53	5.41	34.08	31.19	162.82
	enthalpy	kJ/kg	2,571.8	3,046.8	3,137.7	3,390.3	3,323.8	3,222.5	2,882.1	3,251.5	3,560.9	3,153.8	3,650.2	3,023.9	653.0	653.0	687.5	658.1	2,751.6	911.4	1,018.6	1,660.9
60% (2 × 60%)	mass flow	kg/h	147,545	147,545	202,940	202,940	207,674	147,545	175,281	175,281	175,281	165,725	207,674	24,302	176,771	121,928	176,771	121,928	793	58,362	188	745
	temperature	°C	344.0	425.4	362.0	469.3	441.4	472.8	363.1	467.3	584.9	370.4	584.5	279.3	154.8	154.8	159.7	155.5	154.8	211.3	232.4	344.0
	pressure	bar	153.48	145.62	27.79	26.34	26.34	137.76	137.76	129.90	122.04	27.79	24.89	5.11	5.41	5.41	200.64	33.58	5.41	32.13	29.23	153.48
	enthalpy	kJ/kg	2,600.7	3,083.1	3,148.7	3,392.7	3,330.3	3,248.6	2,843.1	3,244.6	3,569.1	3,168.1	3,651.9	3,021.5	653.0	653.0	685.9	657.7	2,751.6	903.9	1,001.6	1,623.9
50% (1 × 100%)	mass flow	kg/h	220,202	220,202	272,471	272,471	272,553	220,202	238,271	238,271	238,271	225,141	272,553	22,960	239,377	135,897	239,377	135,897	1,018	76,984	238	1,107
	temperature	°C	322.2	439.5	379.3	486.6	486.2	489.4	415.9	510.4	584.9	394.6	584.5	266.9	154.8	154.8	158.8	155.3	154.8	198.4	215.3	322.2
	pressure	bar	116.20	108.34	19.73	18.28	18.28	100.48	100.48	92.62	84.76	19.73	16.84	5.11	5.41	5.41	163.36	25.52	5.41	24.08	21.18	116.20
	enthalpy	kJ/kg	2,693.7	3,198.9	3,203.2	3,440.6	3,439.7	3,346.9	3,144.6	3,410.5	3,602.1	3,236.7	3,658.5	2,995.8	653.0	653.0	679.6	656.4	2,751.6	845.7	922.0	1,475.9
40% (1 × 80%)	mass flow	kg/h	180,313	180,313	245,689	245,689	250,510	180,313	214,587	214,587	214,587	202,789	250,510	19,426	216,408	132,384	216,408	132,384	928	68,731	217	911
	temperature	°C	316.7	438.4	383.1	476.6	452.2	483.7	341.5	468.5	584.9	400.0	584.5	265.1	154.8	154.8	158.6	155.3	154.8	196.5	211.2	316.7
	pressure	bar	108.06	100.20	18.07	16.63	16.63	92.34	92.34	84.48	76.62	18.07	15.18	5.11	5.41	5.41	155.22	23.87	5.41	22.42	19.52	108.06
	enthalpy	kJ/kg	2,710.2	3,209.9	3,214.3	3,420.6	3,367.4	3,342.7	2,917.2	3,314.2	3,608.9	3,251.4	3,660.0	2,992.1	653.0	653.0	678.3	656.1	2,751.6	837.1	903.0	1,442.2
30% (1 × 60%)	mass flow	kg/h	150,651	150,651	212,524	212,524	216,011	150,651	185,587	185,587	185,587	175,399	216,011	15,288	187,109	120,589	187,109	120,589	792	58,271	188	761
	temperature	°C	309.6	441.5	389.3	475.3	454.7	483.7	316.1	457.3	584.8	408.6	584.5	260.8	154.8	154.8	158.3	155.2	154.8	193.9	205.7	309.6
	pressure	bar	98.08	90.22	16.03	14.58	14.58	82.36	82.36	74.50	66.64	16.03	13.13	5.11	5.41	5.41	145.24	21.82	5.41	20.37	17.48	98.08
	enthalpy	kJ/kg	2,728.9	3,234.9	3,231.4	3,420.1	3,375.5	3,355.8	2,851.4	3,300.1	3,617.5	3,273.3	3,661.7	2,983.2	653.0	653.0	676.6	655.8	2,751.6	825.2	878.0	1,399.5
25% (1 × 50%)	mass flow	kg/h	165,338	165,338	189,985	189,985	189,985	165,338	165,338	165,338	165,338	156,286	189,985	14,758	167,008	108,153	167,008	108,153	693	49,321	170	835
	temperature	°C	303.5	454.8	386.2	499.8	499.8	504.0	504.0	542.4	574.1	406.3	569.3	252.2	154.8	154.8	158.1	155.2	154.8	192.3	201.1	303.5
	pressure	bar	90.21	82.35	14.45	13.01	13.01	74.49	74.49	66.63	58.77	14.45	11.56	5.11	5.41	5.41	137.37	20.25	5.41	18.80	15.90	90.21
	enthalpy	kJ/kg	2,742.5	3,282.2	3,227.6	3,475.3	3,475.3	3,415.8	3,415.8	3,516.7	3,599.0	3,270.8	3,629.2	2,965.3	653.0	653.0	675.2	655.5	2,751.6	818.2	857.3	1,364.6

Table 13: Stream tables for NGCC, min DAC, streams and water streams (continued)

	stream number		**142**	**143**	**144**	**145**	**146**	**147**	**148**	**149**	**150**	**151**	**152**	**153**	**154**	**155**	**156**	**157**	**158**	**159**	**160**	**161**
	description		**combined blowdown from both HRSGs**	**combined main steam from both HRSGs**	**combined hot reheat steam from both HRSGs**	**combined cold reheat to both HRSGs**	**combined LP steam from both HRSGs**	**HP turbine valve leak to SSR**	**HP turbine valve leak to hot reheat**	**HP turbine shaft leak to IP turbine**	**HP turbine LP end shaft leak to SSR**	**HP turbine LP end shaft leak to LP steam**	**HP turbine exhaust**	**LP turbine LP end shaft leak to SSR**	**IP turbine exhaust**	**combined steam to SSR**	**condensed DAC steam from regen**	**cooled blowdown to drain**	**condensate from SSR**	**BFW from DAC feedwater pump**	**steam to reclaim after pressure letdown**	**steam to reclaim after spray**
load	phase		**liquid**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**liquid**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	2,758	461,189	523,712	436,086	68,389	398	1,576	14,560	2,927	2,798	438,929	1,678	538,171	5,003	53,774	2,758	5,003	107,548	2,691	3,065
	temperature	°C	238.5	584.2	584.2	355.6	281.4	537.7	537.7	547.2	332.6	332.6	355.6	424.9	424.9	379.2	26.7	53.2	184.9	122.3	342.4	215.6
	pressure	bar	32.58	155.72	31.70	35.27	5.11	35.27	35.27	125.96	11.55	11.55	35.27	11.55	11.55	11.55	1.01	32.24	11.21	2.14	21.30	21.30
	enthalpy	kJ/kg	1,657.5	3,536.6	3,645.5	3,117.8	3,026.0	3,536.6	3,536.6	3,468.2	3,117.8	3,117.8	3,117.8	3,315.3	3,315.3	3,217.4	111.9	225.4	784.9	513.7	3,117.8	2,799.6
90% (2 × 90%)	mass flow	kg/h	2,576	438,514	499,179	414,651	65,558	381	1,501	13,875	2,908	2,558	417,291	1,665	512,890	4,954	51,130	2,576	4,954	102,261	2,498	2,856
	temperature	°C	238.0	584.6	584.5	358.3	280.1	540.2	540.2	547.8	337.0	337.0	358.3	431.5	431.5	383.8	26.7	53.4	184.8	122.3	346.7	215.6
	pressure	bar	32.29	148.78	30.27	33.81	5.11	33.81	33.81	120.34	11.52	11.52	33.81	11.52	11.52	11.52	1.01	31.95	11.18	2.14	21.30	21.30
	enthalpy	kJ/kg	1,625.1	3,543.9	3,647.3	3,127.4	3,023.1	3,543.9	3,543.9	3,475.7	3,127.4	3,127.4	3,127.4	3,329.5	3,329.5	3,227.3	111.9	226.3	784.4	513.7	3,127.4	2,799.6
80% (2 × 80%)	mass flow	kg/h	2,261	409,212	469,943	386,891	59,579	360	1,401	12,975	2,804	2,347	389,325	1,609	482,709	4,774	48,008	2,261	4,774	96,016	2,304	2,646
	temperature	°C	237.3	584.5	584.4	362.1	281.4	543.1	543.1	548.2	342.6	342.6	362.1	435.7	435.7	388.6	26.7	53.6	183.4	122.3	352.3	215.6
	pressure	bar	31.93	139.54	28.54	32.04	5.11	32.04	32.04	112.86	11.17	11.17	32.04	11.17	11.17	11.17	1.01	31.58	10.83	2.14	21.30	21.30
	enthalpy	kJ/kg	1,576.5	3,552.1	3,648.6	3,140.1	3,025.8	3,552.1	3,552.1	3,484.3	3,140.1	3,140.1	3,140.1	3,338.9	3,338.9	3,238.2	111.9	226.9	778.1	513.7	3,140.1	2,799.6
70% (2 × 70%)	mass flow	kg/h	2,057	379,254	437,532	358,557	54,042	336	1,300	12,056	2,707	2,094	360,760	1,555	449,333	4,598	44,506	2,057	4,598	89,013	2,085	2,407
	temperature	°C	236.6	584.5	584.4	366.2	280.5	546.2	546.2	548.8	348.7	348.7	366.2	441.9	441.9	394.3	26.7	53.8	182.0	122.3	358.4	215.6
	pressure	bar	31.50	130.06	26.57	30.04	5.11	30.04	30.04	105.20	10.85	10.85	30.04	10.85	10.85	10.85	1.01	31.15	10.50	2.14	21.30	21.30
	enthalpy	kJ/kg	1,536.4	3,560.9	3,650.2	3,153.8	3,023.9	3,560.9	3,560.9	3,493.6	3,153.8	3,153.8	3,153.8	3,352.6	3,352.6	3,250.8	111.9	227.8	772.1	513.7	3,153.8	2,799.6
60% (2 × 60%)	mass flow	kg/h	1,866	350,562	405,880	331,450	48,604	314	1,203	11,166	2,632	1,827	333,420	1,512	416,737	4,458	40,972	1,866	4,458	81,943	1,865	2,165
	temperature	°C	235.8	584.5	584.4	370.7	279.3	549.0	549.0	549.3	355.2	355.2	370.7	449.9	449.9	400.6	26.7	54.1	181.0	122.3	364.8	215.6
	pressure	bar	31.05	120.82	24.64	28.07	5.11	28.07	28.07	97.73	10.61	10.61	28.07	10.61	10.61	10.61	1.01	30.71	10.26	2.14	21.30	21.30
	enthalpy	kJ/kg	1,498.5	3,569.1	3,651.9	3,168.1	3,021.5	3,569.1	3,569.1	3,502.6	3,168.1	3,168.1	3,168.1	3,370.1	3,370.1	3,264.8	111.9	229.1	767.7	513.7	3,168.1	2,799.6
50% (1 × 100%)	mass flow	kg/h	1,344	238,271	272,471	225,141	22,960	221	821	7,658	1,583	1,497	226,490	941	280,010	2,744	28,194	1,344	2,744	56,389	1,276	1,521
	temperature	°C	231.8	584.6	584.4	394.7	266.9	560.4	560.4	553.0	384.2	384.2	394.7	437.6	437.6	416.5	26.7	54.1	160.2	122.3	394.7	212.2
	pressure	bar	28.93	83.91	16.67	19.93	5.11	19.93	19.93	67.87	6.56	6.56	19.93	6.56	6.56	6.56	1.01	28.58	6.21	2.14	19.93	19.93
	enthalpy	kJ/kg	2,755.7	3,602.1	3,658.5	3,236.7	2,995.8	3,602.1	3,602.1	3,540.7	3,236.7	3,236.7	3,236.7	3,349.3	3,349.3	3,304.7	111.9	228.7	676.4	513.7	3,236.7	2,798.3
40% (1 × 80%)	mass flow	kg/h	1,127	214,587	245,689	202,789	19,426	202	738	6,905	1,532	1,274	203,936	908	252,425	2,641	25,138	1,127	2,641	50,277	1,085	1,300
	temperature	°C	230.9	584.6	584.5	400.1	265.1	562.8	562.8	553.6	391.1	391.1	400.1	448.8	448.8	423.9	26.7	54.5	159.0	122.3	400.1	207.8
	pressure	bar	28.41	75.86	15.03	18.26	5.11	18.26	18.26	61.36	6.38	6.38	18.26	6.38	6.38	6.38	1.01	28.07	6.03	2.14	18.26	18.26
	enthalpy	kJ/kg	2,677.1	3,608.9	3,660.0	3,251.4	2,992.1	3,608.9	3,608.9	3,548.4	3,251.4	3,251.4	3,251.4	3,373.4	3,373.4	3,320.6	111.9	230.6	671.4	513.7	3,251.4	2,796.3
30% (1 × 60%)	mass flow	kg/h	948	185,587	212,524	175,399	15,288	178	637	5,986	1,434	1,034	176,318	849	218,299	2,461	21,319	948	2,461	42,639	868	1,051
	temperature	°C	229.5	584.6	584.5	408.7	260.8	565.8	565.8	554.7	401.3	401.3	408.7	461.8	461.8	434.0	26.7	55.1	156.7	122.3	408.7	201.9
	pressure	bar	27.73	65.98	13.00	16.19	5.11	16.19	16.19	53.36	6.02	6.02	16.19	6.02	6.02	6.02	1.01	27.39	5.67	2.14	16.19	16.19
	enthalpy	kJ/kg	2,592.9	3,617.5	3,661.7	3,273.3	2,983.2	3,617.5	3,617.5	3,558.5	3,273.3	3,273.3	3,273.3	3,401.4	3,401.4	3,342.4	111.9	233.0	661.1	513.7	3,273.3	2,793.2
25% (1 × 50%)	mass flow	kg/h	1,005	165,338	189,985	156,286	14,758	162	561	5,304	1,291	937	157,084	768	195,081	2,221	18,214	1,005	2,221	36,427	755	913
	temperature	°C	228.4	573.9	569.2	406.4	252.2	556.9	556.9	545.0	399.6	399.6	406.4	451.5	451.5	429.0	26.7	55.1	152.3	122.3	406.4	197.0
	pressure	bar	27.16	58.18	11.44	14.60	5.11	14.60	14.60	47.06	5.41	5.41	14.60	5.41	5.41	5.41	1.01	26.82	5.07	2.14	14.60	14.60
	enthalpy	kJ/kg	2,557.4	3,599.0	3,629.2	3,270.8	2,965.3	3,599.0	3,599.0	3,542.0	3,270.8	3,270.8	3,270.8	3,380.4	3,380.4	3,332.6	111.9	233.1	642.4	513.7	3,270.8	2,790.2

Table 13: Stream tables for NGCC, min DAC, streams and water streams (continued)

	stream number		162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
	description		spray water to reclaim attemp.	condensate return from reclaim	steam to CO_2 drying after pressure letdown	spray water to CO_2 drying attemp.	steam to CO_2 drying after spray	condensate return from CO_2 drying	combined condensate from reclaim and CO_2 drying	steam to PCC reboiler after pressure letdown	steam to PCC reboiler after desuperheat	condensate from PCC reboiler	condensate entering condensate cooler, HX-3	condensate exiting condensate cooler, HX-3	condensate exiting LP steam condenser HX-7	attemp. spray pump discharge	from IP turbine exhaust to LP turbine or DAC steam generator	LP steam from HRSG to HX-7	LP steam from HRSGs to LP turbine	steam exhausting from first LP turbine	steam entering second LP turbine	LP steam to HX-7
load	phase		liquid	liquid	vapor	liquid	vapor	liquid	liquid	vapor	vapor	liquid	liquid	liquid	liquid	liquid	vapor	vapor	vapor	vapor	vapor	vapor
100% (2 × 100%)	mass flow	kg/h	374	3,065	153	22	174	174	3,239	335,719	335,719	335,719	338,958	338,958	0	395	205,249	0	65,983	205,249	271,233	0
	temperature	°C	120.6	214.8	338.2	120.6	204.4	203.4	203.4	420.7	152.3	149.7	149.7	120.0	0	38.5	424.4	0	281.4	316.2	307.8	0
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	11.55	0	5.11	5.11	5.11	0
	enthalpy	kJ/kg	507.9	919.5	3,117.8	507.9	2,794.6	867.8	916.8	3,315.3	2,748.7	631.0	633.7	504.0	0	507.7	3,315.3	0	3,026.0	3,097.8	3,080.3	0
90% (2 × 90%)	mass flow	kg/h	357	2,856	142	21	162	162	3,018	312,823	312,823	312,823	315,841	315,841	0	378	202,624	0	63,269	202,624	265,893	0
	temperature	°C	120.6	214.8	342.5	120.6	204.4	203.4	203.4	427.5	152.3	149.7	149.7	120.0	0	38.5	431.1	0	280.1	322.3	312.2	0
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	11.52	0	5.11	5.11	5.05	0
	enthalpy	kJ/kg	507.9	919.5	3,127.4	507.9	2,794.6	867.8	916.8	3,329.5	2,748.7	631.0	633.7	504.0	0	507.7	3,329.5	0	3,023.1	3,110.5	3,089.7	0
80% (2 × 80%)	mass flow	kg/h	342	2,646	131	20	150	150	2,797	289,877	289,877	289,877	292,674	292,674	0	362	195,178	0	57,431	195,178	252,610	0
	temperature	°C	120.6	214.8	348.3	120.6	204.4	203.4	203.4	432.0	152.3	149.7	149.7	120.0	0	38.5	435.2	0	281.4	329.9	318.6	0
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	11.17	0	5.11	5.11	4.86	0
	enthalpy	kJ/kg	507.9	919.5	3,140.1	507.9	2,794.6	867.8	916.8	3,338.9	2,748.7	631.0	633.7	504.0	0	507.7	3,338.9	0	3,025.8	3,126.1	3,103.3	0
70% (2 × 70%)	mass flow	kg/h	322	2,407	118	19	137	137	2,544	263,724	263,724	263,724	266,269	266,269	0	341	187,702	0	52,050	187,702	239,752	0
	temperature	°C	120.6	214.8	354.5	120.6	204.4	203.4	203.4	438.4	152.3	149.7	149.7	120.0	0	38.5	441.4	0	280.5	339.1	325.9	0
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	10.85	0	5.11	5.11	4.67	0
	enthalpy	kJ/kg	507.9	919.5	3,153.8	507.9	2,794.6	867.8	916.8	3,352.6	2,748.7	631.0	633.7	504.0	0	507.7	3,352.6	0	3,023.9	3,145.3	3,118.9	0
60% (2 × 60%)	mass flow	kg/h	300	2,165	106	17	123	123	2,288	237,140	237,140	237,140	239,428	239,428	0	317	181,424	0	46,769	181,424	228,193	0
	temperature	°C	120.6	214.8	361.0	120.6	204.4	203.4	203.4	446.7	152.3	149.7	149.7	120.0	0	38.5	449.5	0	279.3	349.1	334.2	0
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	10.61	0	5.11	5.11	4.51	0
	enthalpy	kJ/kg	507.9	919.5	3,168.1	507.9	2,794.6	867.8	916.8	3,370.1	2,748.7	631.0	633.7	504.0	0	507.7	3,370.1	0	3,021.5	3,165.9	3,136.3	0
50% (1 × 100%)	mass flow	kg/h	244	1,521	73	14	87	87	1,608	167,860	167,860	167,860	169,467	169,467	0	258	113,647	0	21,685	113,647	135,332	0
	temperature	°C	120.6	211.3	392.5	120.6	204.4	203.4	203.4	436.9	152.3	149.7	149.7	120.0	0	38.5	437.3	0	266.9	402.3	378.9	0
	pressure	bar	27.59	19.59	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	6.56	0	5.11	5.11	2.88	0
	enthalpy	kJ/kg	507.9	903.8	3,236.7	507.9	2,794.6	867.8	901.8	3,349.3	2,748.7	631.0	633.5	504.0	0	507.7	3,349.3	0	2,995.8	3,276.9	3,231.8	0
40% (1 × 80%)	mass flow	kg/h	216	1,300	63	13	75	75	1,376	144,939	144,939	144,939	146,314	146,314	0	228	108,760	0	18,288	108,760	127,048	0
	temperature	°C	120.6	206.9	399.2	120.6	204.4	203.4	203.4	448.2	152.3	149.7	149.7	120.0	0	38.5	448.5	0	265.1	416.9	393.5	0
	pressure	bar	27.59	17.91	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	0	27.58	6.38	0	5.11	5.11	2.77	0
	enthalpy	kJ/kg	507.9	883.5	3,251.4	507.9	2,794.6	867.8	882.7	3,373.4	2,748.7	631.0	633.3	504.0	0	507.7	3,373.4	0	2,992.1	3,307.7	3,262.3	0
30% (1 × 60%)	mass flow	kg/h	182	1,051	51	11	61	61	1,112	118,570	118,570	118,570	119,682	119,682	0	193	100,763	0	14,319	100,763	115,082	0
	temperature	°C	120.6	200.9	408.7	120.6	204.4	200.9	200.9	461.4	152.3	149.7	149.7	120.0	0	38.5	461.5	0	260.8	437.8	414.2	0
	pressure	bar	27.59	15.85	16.19	27.59	16.19	15.85	15.85	5.41	5.07	4.72	4.72	4.38	0	27.58	6.02	0	5.11	5.11	2.59	0
	enthalpy	kJ/kg	507.9	856.5	3,273.3	507.9	2,793.2	856.5	856.5	3,401.4	2,748.7	631.0	633.1	504.0	0	507.7	3,401.4	0	2,983.2	3,351.6	3,305.8	0
25% (1 × 50%)	mass flow	kg/h	159	913	44	9	53	53	967	104,124	104,124	104,124	105,091	105,091	0	168	91,894	0	13,926	91,894	105,820	0
	temperature	°C	120.6	195.9	406.4	120.6	204.4	195.9	195.9	451.5	152.3	149.7	149.7	120.0	0	38.5	451.3	0	252.2	443.1	416.4	0
	pressure	bar	27.59	14.26	14.60	27.59	14.60	14.26	14.26	5.41	5.07	4.72	4.72	4.38	0	27.58	5.41	0	5.11	5.11	2.39	0
	enthalpy	kJ/kg	507.9	833.9	3,270.8	507.9	2,790.2	833.9	833.9	3,380.4	2,748.7	631.0	632.8	504.0	0	507.7	3,380.4	0	2,965.3	3,362.9	3,310.6	0

Table 13: Stream tables for NGCC, min DAC, streams and water streams (continued)

	stream number		182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198
	description		**DAC steam lost to atmosphere during regen**	**steam from IP turbine to LP turbine**	**condensate entering HX-8**	**condensate exiting HX-9**	**makeup water for HRSG**	**exhaust from LP turbine 2 to HX-6**	**condensate exiting from HX-6**	**condensate from condensate pump to HRSGs**	**condensate from SSR**	**steam to DAC**	**condensate to one HRSG LP economizer**	**makeup water to DAC supply**	**condensate from DAc condensate supply pump**	**LP steam to DAC decarbonator**	**condensate to DAC decarbonator**	**vent from DAC decarbonator**	**condensate between HX-8 and HX-9**
load	phase		**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**mixed**	**liquid**	**liquid**	**liquid**	**vapor**	**liquid**	**liquid**	**liquid**	**vapor**	**liquid**	**vapor**	**liquid**
100% (2 × 100%)	mass flow	kg/h	53,775	205,249	338,563	338,563	7,200	271,233	271,233	621,999	621,999	107,548	340,415	51,584	105,358	2,405	105,358	215	338,563
	temperature	°C	100.0	424.4	120.0	37.8	26.7	38.4	38.4	38.5	43.2	110.0	46.1	26.7	26.7	281.4	110.0	122.3	94.3
	pressure	bar	1.01	11.55	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,315.3	504.0	158.6	112.4	2,382.3	160.8	161.8	181.4	2,691.1	193.5	111.9	112.2	3,026.0	461.4	535.0	395.3
90%(2 × 90%)	mass flow	kg/h	51,131	202,624	315,463	315,463	4,694	265,893	265,893	591,004	591,004	102,261	322,909	49,046	100,176	2,289	100,176	205	315,463
	temperature	°C	100.0	431.1	120.0	37.8	26.7	38.4	38.4	38.5	43.4	110.0	46.2	26.7	26.7	280.1	110.0	122.3	93.8
	pressure	bar	1.01	11.52	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,329.5	504.0	158.6	112.4	2,389.1	160.8	161.8	182.3	2,691.1	194.0	111.9	112.2	3,023.1	461.4	535.0	393.1
80%(2 × 80%)	mass flow	kg/h	48,009	195,178	292,312	292,312	6,266	252,610	252,610	555,951	555,951	96,016	303,373	46,053	94,061	2,148	94,061	192	292,312
	temperature	°C	100.0	435.2	120.0	37.8	26.7	38.4	38.4	38.5	43.6	110.0	46.2	26.7	26.7	281.4	110.0	122.3	93.4
	pressure	bar	1.01	11.17	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,338.9	504.0	158.6	112.4	2,402.0	160.8	161.8	182.9	2,691.1	194.0	111.9	112.2	3,025.8	461.4	535.0	391.6
70%(2 × 70%)	mass flow	kg/h	44,507	187,702	265,928	265,928	5,770	239,752	239,752	516,048	516,048	89,013	281,127	42,693	87,199	1,992	87,199	178	265,928
	temperature	°C	100.0	441.4	120.0	37.8	26.7	38.4	38.4	38.5	43.8	110.0	46.3	26.7	26.7	280.5	110.0	122.3	92.9
	pressure	bar	1.01	10.85	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,352.6	504.0	158.6	112.4	2,416.0	160.8	161.8	183.9	2,691.1	194.5	111.9	112.2	3,023.9	461.4	535.0	389.5
60% (2 × 60%)	mass flow	kg/h	40,972	181,424	239,111	239,111	5,287	228,193	228,193	477,048	477,048	81,943	259,294	39,300	80,272	1,836	80,272	164	239,111
	temperature	°C	100.0	449.5	120.0	37.8	26.7	38.4	38.4	38.5	44.1	110.0	46.5	26.7	26.7	279.3	110.0	122.3	92.3
	pressure	bar	1.01	10.61	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,370.1	504.0	158.6	112.4	2,430.2	160.8	161.8	185.1	2,691.1	195.3	111.9	112.2	3,021.5	461.4	535.0	386.7
50% (1 × 100%)	mass flow	kg/h	28,195	113,647	169,209	169,209	3,637	135,332	135,332	310,924	310,924	56,389	340,340	27,033	55,227	1,275	55,227	113	169,209
	temperature	°C	100.0	437.3	120.0	37.8	26.7	38.4	38.4	38.5	44.1	110.0	47.9	26.7	26.7	266.9	110.0	122.3	93.0
	pressure	bar	1.01	6.56	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,349.3	504.0	158.6	112.4	2,540.0	160.8	161.8	185.0	2,691.1	201.0	111.9	112.2	2,995.8	461.4	535.0	390.0
40% (1 × 80%)	mass flow	kg/h	25,139	108,760	146,086	146,086	3,194	127,048	127,048	278,969	278,969	50,277	304,366	24,101	49,239	1,138	49,239	101	146,086
	temperature	°C	100.0	448.5	120.0	37.8	26.7	38.4	38.4	38.5	44.5	110.0	48.0	26.7	26.7	265.1	110.0	122.3	92.1
	pressure	bar	1.01	6.38	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,373.4	504.0	158.6	112.4	2,561.0	160.8	161.8	186.9	2,691.1	201.6	111.9	112.2	2,992.1	461.4	535.0	386.3
30% (1 × 60%)	mass flow	kg/h	21,320	100,763	119,489	119,489	2,709	115,082	115,082	239,741	239,741	42,639	260,512	20,437	41,756	968	41,756	85	119,489
	temperature	°C	100.0	461.5	120.0	37.8	26.7	49.5	38.4	38.5	45.1	110.0	48.4	26.7	26.7	260.8	110.0	122.3	91.1
	pressure	bar	1.01	6.02	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,401.4	504.0	158.6	112.4	2,591.9	160.8	161.8	189.3	2,691.1	203.1	111.9	112.2	2,983.2	461.4	535.0	381.9
25% (1 × 50%)	mass flow	kg/h	18,214	91,894	104,923	104,923	2,531	105,820	105,820	215,494	215,494	36,427	230,776	17,454	35,668	833	35,668	73	104,923
	temperature	°C	100.0	451.3	120.0	37.8	26.7	56.3	38.4	38.5	45.1	110.0	48.6	26.7	26.7	252.2	110.0	122.3	91.9
	pressure	bar	1.01	5.41	4.38	3.69	6.89	.07	.07	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	3,380.4	504.0	158.6	112.4	2,604.9	160.8	161.8	189.5	2,691.1	204.0	111.9	112.2	2,965.3	461.4	535.0	385.3

Table 14: Stream tables for NGCC, min DAC, gas streams

	stream number		201	202	203	204	205	206	207	208	209	210	211
	description		**total flue gas entering HPSH4**	**total flue gas entering IPSH3**	**total flue gas entering HPSH3**	**total flue gas entering HPSH2**	**total flue gas entering IPSH2**	**total flue gas entering HPSH1**	**total flue gas entering HPEVAP**	**total flue gas entering HPEC5**	**total flue gas entering IPSH1**	**total flue gas entering HPEC4**	**total flue gas entering HPEC3**
load	phase		**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395
	temperature	°C	625.0	605.9	577.2	555.0	533.8	499.8	452.2	369.4	347.1	341.5	334.3
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
90% (2 × 90%)	mass flow	kg/h	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315
	temperature	°C	628.2	607.0	576.6	551.2	531.2	497.7	450.5	366.0	344.9	339.3	332.5
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
80% (2 × 80%)	mass flow	kg/h	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583
	temperature	°C	644.3	613.8	573.6	538.1	520.6	488.9	444.5	361.0	343.0	337.1	331.3
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
70% (2 × 70%)	mass flow	kg/h	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408
	temperature	°C	644.3	612.3	572.2	533.5	517.4	486.5	442.5	356.1	339.8	333.8	328.5
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
60% (2 × 60)	mass flow	kg/h	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982
	temperature	°C	644.3	610.7	570.9	528.7	514.0	483.9	440.4	351.0	336.3	330.2	325.5
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
50% (1 × 100%)	mass flow	kg/h	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697
	temperature	°C	625.0	604.9	578.5	550.3	535.7	506.7	456.2	334.8	319.1	313.7	307.8
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
40% (1 × 80%)	mass flow	kg/h	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791
	temperature	°C	644.3	612.4	575.1	531.4	519.1	492.8	445.8	327.7	314.7	309.1	304.2
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
30% (1 × 60%)	mass flow	kg/h	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991
	temperature	°C	644.3	609.5	572.7	522.7	511.7	487.4	440.7	319.2	308.1	302.5	298.3
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05
25% (1 × 50%)	mass flow	kg/h	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236
	temperature	°C	587.7	579.5	561.8	551.7	538.3	509.5	454.4	314.5	301.1	296.0	290.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05

	stream number		212	213	214	215	216	217	218	219	220	221	222
	description		**total flue gas entering LPSH**	**total flue gas entering IPEVAP**	**total flue gas entering IPEC2**	**total flue gas entering HPEC2**	**total flue gas entering IPEC1**	**total flue gas entering HPEC1**	**total flue gas entering LPEVAP**	**total flue gas entering LPECON**	**total flue gas exiting stack**	**total ambient air entering gas turbine**	**total natural gas entering gas turbine**
load	phase		**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,834,106	93,272
	temperature	°C	294.2	289.8	253.1	250.6	238.3	228.8	200.6	163.2	89.2	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
90% (2 × 90%)	mass flow	kg/h	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,628,398	86,901
	temperature	°C	292.6	288.1	250.6	248.1	236.6	227.1	199.7	162.8	87.2	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
80% (2 × 80%)	mass flow	kg/h	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,339,037	80,531
	temperature	°C	292.6	288.2	247.8	245.3	235.3	225.6	199.8	162.4	85.0	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
70% (2 × 70%)	mass flow	kg/h	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,096,138	73,256
	temperature	°C	290.3	285.9	244.1	241.8	232.7	223.1	198.5	161.8	84.6	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
60% (2 × 60)	mass flow	kg/h	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,856,110	65,859
	temperature	°C	287.7	283.5	240.5	238.2	229.8	220.5	197.1	161.3	84.3	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
50% (1 × 100%)	mass flow	kg/h	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,917,053	46,636
	temperature	°C	270.4	267.7	225.2	223.3	215.2	208.1	188.4	161.0	88.5	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
40% (1 × 80%)	mass flow	kg/h	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,669.518	40,265
	temperature	°C	267.7	265.1	220.6	218.8	212.0	205.0	186.9	160.3	85.6	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
30% (1 × 60%)	mass flow	kg/h	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,428,055	32,930
	temperature	°C	262.3	260.0	214.4	212.8	206.9	200.4	184.1	159.3	84.9	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
25% (1 × 50%)	mass flow	kg/h	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,414,420	28,891
	temperature	°C	253.4	251.4	209.1	207.9	201.5	196.3	180.3	158.7	90.7	15.0	26.7
	pressure	bar	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6

Table 15: Stream tables for NGCC, max DAC, streams and water streams

	stream number		**102**	**103**	**104**	**105**	**106**	**107**	**108/108A**	**109**	**110**	**111/111A**	**112**	**113/113A**	**114/114A**	**115**	**116**	**117**	**118**	**119**	**120**	**121**
	description		**total condensate to both HRSGs**	**condensate to one HRSG**	**condensate entering the LP evaporator**	**condensate from LP evaporator to pumps**	**LP steam from evaporator**	**HP BFW from pump To HP Econ 1**	**spray water for main steam DSH**	**HP BFW from HP Econ 1 to HP Econ 2**	**IP BFW from pump to IP Econ 1**	**spray water for reheat DSH**	**IP BFW from IP Econ 1 to IP Econ 2**	**hot BFW supply to NG preheater**	**BFW return from NG preheater**	**IP BFW entering the IP evaporator**	**HP BFW from HP Econ 2 to HP Econ 3**	**IP steam from evaporator**	**HP BFW from HP Econ 3 to HP Econ 4**	**HP BFW from HP Econ 4 To HP Econ 5**	**HP BFW entering the HP evaporator**	**IP steam exiting IP SH1**
load	phase		**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Vapor**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Liquid**	**Vapor**	**Liquid**	**Liquid**	**Liquid**	**Vapor**
100% (2 × 100%)	mass flow	kg/h	621,863	310,932	340,348	305,210	34,119	231,769	0	231,769	73,441	0	44,025	58,832	58,832	44,025	231,769	43,805	231,769	231,769	231,769	43,805
	temperature	°C	44.7	44.7	152.6	154.8	154.8	160.6	160.6	218.5	155.7	155.7	216.9	216.9	60.0	242.3	242.9	244.8	316.0	327.1	355.1	335.8
	pressure	bar	6.00	6.00	5.70	5.41	5.41	235.90	235.90	228.04	40.71	40.71	39.26	39.26	40.33	37.81	220.18	36.37	212.32	204.46	196.60	34.92
	enthalpy	kJ/kg	187.7	187.7	643.4	653.0	2,751.6	691.9	691.9	943.7	659.0	658.9	930.0	930.0	254.5	1,048.8	1,054.1	2,802.4	1,420.4	1,486.8	1,693.2	3,070.4
90%(2 × 90%)	mass flow	kg/h	593,120	296,560	326,325	292,575	32,773	214,931	6,476	214,931	70,099	1,070	42,692	54,813	54,813	42,692	214,931	42,265	214,931	214,931	214,931	42,265
	temperature	°C	44.9	44.9	152.1	154.8	154.8	160.4	160.4	217.8	155.7	155.7	215.8	215.8	60.0	240.1	241.2	242.4	315.3	326.0	353.1	333.8
	pressure	bar	6.00	6.00	5.70	5.41	5.41	228.88	228.88	221.02	39.27	39.27	37.82	37.82	40.33	36.37	213.16	34.92	205.30	197.44	189.58	33.47
	enthalpy	kJ/kg	188.3	188.3	641.2	653.0	2,751.6	690.7	690.7	940.0	658.8	658.7	925.0	925.0	254.5	1,038.2	1,045.8	2,802.8	1,417.3	1,481.5	1,680.1	3,069.1
80%(2 × 80%)	mass flow	kg/h	555,951	277,975	310,469	279,751	29,789	184,169	22,278	184,169	67,343	5,960	41,945	50,796	50,796	41,945	184,169	41,526	184,169	184,169	184,169	41,526
	temperature	°C	44.9	44.9	151.0	154.8	154.8	160.2	160.2	218.3	155.6	155.6	214.4	214.4	60.0	237.3	240.1	239.5	316.8	326.4	351.0	331.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	219.55	219.55	211.69	37.51	37.51	36.06	36.06	40.33	34.62	203.83	33.17	195.97	188.11	180.25	31.72
	enthalpy	kJ/kg	188.4	188.4	636.4	653.0	2,751.6	689.1	689.1	942.0	658.5	658.4	918.5	918.5	254.5	1,024.7	1,040.5	2,803.1	1,427.5	1,485.9	1,667.8	3,066.9
70%(2 × 70%)	mass flow	kg/h	516,048	258,024	287,612	259,731	27,021	165,822	25,463	165,822	62,989	5,457	39,886	46,207	46,207	39,886	165,822	39,487	165,822	165,822	165,822	39,487
	temperature	°C	45.0	45.0	150.9	154.8	154.8	159.9	159.9	216.9	155.6	155.6	212.9	212.9	60.0	234.3	237.3	236.0	315.6	324.5	347.7	328.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	209.98	209.98	202.12	35.53	35.53	34.08	34.08	40.33	32.63	194.26	31.19	186.40	178.54	170.68	29.74
	enthalpy	kJ/kg	189.1	189.1	636.3	653.0	2,751.6	687.5	687.5	935.4	658.2	658.1	911.4	911.4	254.5	1,010.6	1,027.7	2,803.3	1,421.5	1,475.9	1,645.0	3,064.8
60% (2 × 60%)	mass flow	kg/h	477,007	238,504	264,948	239,869	24,287	149,049	27,724	149,049	58,355	4,740	37,584	41,541	41,541	37,584	149,049	37,209	149,049	149,049	149,049	37,209
	temperature	°C	45.3	45.3	150.9	154.8	154.8	159.7	159.7	215.2	155.5	155.5	211.3	211.3	60.0	231.4	234.5	232.4	313.8	322.2	344.1	325.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	200.64	200.64	192.78	33.58	33.58	32.13	32.13	40.33	30.68	184.92	29.23	177.06	169.20	161.34	27.79
	enthalpy	kJ/kg	190.1	190.1	636.3	653.0	2,751.6	686.0	685.9	927.4	657.8	657.7	903.9	903.9	254.5	996.8	1,014.5	2,803.2	1,412.8	1,463.4	1,619.9	3,062.5
50% (1 × 100%)	mass flow	kg/h	310,921	310,921	340,421	316,442	22,960	221,308	18,069	221,308	76,984	82	47,568	29,416	29,416	47,568	221,308	47,330	221,308	221,308	221,308	47,330
	temperature	°C	46.7	46.7	150.8	154.8	154.8	158.8	158.8	201.3	155.3	155.3	198.4	198.4	60.0	216.5	218.4	215.3	292.1	302.2	326.6	308.1
	pressure	bar	6.00	6.00	5.70	5.41	5.41	163.36	163.36	155.50	25.52	25.52	24.08	24.08	40.33	22.63	147.64	21.18	139.78	131.92	124.06	19.73
	enthalpy	kJ/kg	196.0	196.0	635.7	653.0	2,751.6	679.7	679.6	864.2	656.5	656.4	845.7	845.7	254.5	927.6	940.3	2,799.5	1,296.3	1,352.3	1,502.9	3,043.7
40% (1 × 80%)	mass flow	kg/h	278,951	278,951	310,314	289,965	19,421	182,145	34,256	182,145	68,726	4,838	43,328	25,398	25,398	43,328	182,145	42,895	182,145	182,145	182,145	42,895
	temperature	°C	46.9	46.9	149.2	154.8	154.8	158.6	158.6	199.9	155.3	155.3	196.5	196.5	60.0	212.8	215.2	211.2	291.3	300.3	321.9	304.1
	pressure	bar	6.00	6.00	5.70	5.41	5.41	155.22	155.22	147.36	23.87	23.87	22.42	22.42	40.33	20.97	139.50	19.52	131.64	123.78	115.92	18.07
	enthalpy	kJ/kg	196.8	196.8	628.8	653.0	2,751.6	678.3	678.3	857.5	656.2	656.1	837.1	837.1	254.5	910.6	925.5	2,797.9	1,292.5	1,341.9	1,473.3	3,039.1
30% (1 × 60%)	mass flow	kg/h	239,712	239,712	264,946	248,877	15,277	152,206	34,890	152,206	58,266	3,515	37,495	20,770	20,770	37,495	152,206	37,120	152,206	152,206	152,206	37,120
	temperature	°C	47.3	47.3	149.3	154.8	154.8	158.3	158.3	196.4	155.2	155.2	193.9	193.9	60.0	208.1	210.1	205.7	287.3	295.4	315.0	299.0
	pressure	bar	6.00	6.00	5.70	5.41	5.41	145.24	145.24	137.38	21.82	21.82	20.37	20.37	40.33	18.92	129.52	17.48	121.66	113.80	105.94	16.03
	enthalpy	kJ/kg	198.7	198.7	629.4	653.0	2,751.6	676.6	676.6	841.8	655.9	655.8	825.1	825.1	254.5	889.0	902.4	2,795.2	1,272.1	1,316.2	1,431.1	3,033.1
25% (1 × 50%)	mass flow	kg/h	215,491	215,491	231,778	216,333	14,752	167,008	0	167,008	49,324	0	34,043	15,282	15,282	34,043	167,008	33,703	167,008	167,008	167,008	33,703
	temperature	°C	47.7	47.7	152.7	154.8	154.8	158.1	158.1	191.5	155.2	155.2	192.3	192.3	60.0	204.4	204.6	201.1	277.4	286.9	308.8	294.2
	pressure	bar	6.00	6.00	5.70	5.41	5.41	137.37	137.37	129.51	20.25	20.25	18.80	18.80	40.33	17.35	121.65	15.90	113.79	105.93	98.07	14.45
	enthalpy	kJ/kg	200.4	200.4	643.8	653.0	2,751.6	675.3	675.2	819.7	655.6	655.5	818.2	818.2	254.5	872.3	877.1	2,792.7	1,220.9	1,270.5	1,394.9	3,026.8

Table 15: Stream tables for NGCC, max DAC, streams and water streams (continued)

	stream number		122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141
	description		**HP steam from evaporator**	**HP steam from HP SH 1 to HP SH 2**	**combined cold reheat steam plus IP steam from HRSG**	**IP steam from IP SH 2/RH 1 to RH DSH**	**IP steam from RH DSH to IP SH 3/RH 2**	**HP steam from HP SH 2 to MS DSH**	**HP steam from MS DSH to HP SH 3**	**HP steam from HP SH 3 tO HP SH 4**	**main steam from one HRSG**	**cold reheat to one HRSG**	**hot reheat from one HRSG**	**LP steam from one HRSG**	**HP pump suction**	**IP pump suction**	**HP pump discharge**	**IP pump discharge**	**deaerator vent**	**combined flow exiting IP Econ 1**	**IP evaporator blowdown**	**HP evaporator blowdown**
load	phase		**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**
100% (2 × 100%)	mass flow	kg/h	230,610	230,610	261,864	261,864	261,864	230,610	230,610	230,610	230,610	218,058	261,864	34,119	231,769	132,273	231,769	132,273	1,018	73,441	220	1,159
	temperature	°C	360.9	408.3	352.0	475.8	475.8	454.5	454.5	519.7	584.8	355.3	584.3	281.5	154.8	154.8	160.6	155.7	154.8	216.9	244.8	360.9
	pressure	bar	188.74	180.88	34.92	33.47	33.47	173.02	173.02	165.16	157.30	34.92	32.02	5.11	5.41	5.41	235.90	40.71	5.41	39.26	36.37	188.74
	enthalpy	kJ/kg	2,471.4	2,925.5	3,109.9	3,398.4	3,398.4	3,131.2	3,131.2	3,348.3	3,536.6	3,117.8	3,645.4	3,026.1	653.0	653.0	691.9	658.9	2,751.6	930.0	1,060.4	1,771.0
90% (2 × 90%)	mass flow	kg/h	212,781	212,781	249,591	249,591	250,661	212,781	219,257	219,257	219,257	207,326	250,661	32,773	221,407	130,001	221,407	130,001	976	70,099	213	1,075
	temperature	°C	357.8	412.4	353.8	475.5	470.3	460.2	439.3	512.3	585.1	358.0	584.6	280.1	154.8	154.8	160.4	155.7	154.8	215.8	242.4	357.8
	pressure	bar	181.72	173.86	33.47	32.03	32.03	166.00	166.00	158.14	150.28	33.47	30.58	5.11	5.41	5.41	228.88	39.27	5.41	37.82	34.92	181.72
	enthalpy	kJ/kg	2,502.5	2,964.2	3,117.5	3,399.6	3,387.9	3,163.3	3,090.3	3,335.9	3,543.9	3,127.4	3,647.3	3,023.1	653.0	653.0	690.7	658.7	2,751.6	925.0	1,049.2	1,739.5
80% (2 × 80%)	mass flow	kg/h	182,328	182,328	234,971	234,971	240,931	182,328	204,606	204,606	204,606	193,445	240,931	29,789	206,448	132,135	206,448	132,135	929	67,343	210	921
	temperature	°C	353.4	416.2	356.3	469.3	439.3	463.7	391.5	481.3	585.0	361.8	584.5	281.4	154.8	154.8	160.2	155.6	154.8	214.4	239.5	353.4
	pressure	bar	172.39	164.53	31.72	30.27	30.27	156.67	156.67	148.81	140.95	31.72	28.82	5.11	5.41	5.41	219.55	37.51	5.41	36.06	33.17	172.39
	enthalpy	kJ/kg	2,538.8	3,004.7	3,127.2	3,387.6	3,320.1	3,190.6	2,918.2	3,257.5	3,552.1	3,140.1	3,648.6	3,025.8	653.0	653.0	689.1	658.4	2,751.6	918.5	1,035.1	1,699.9
70% (2 × 70%)	mass flow	kg/h	164,164	164,164	218,766	218,766	224,222	164,164	189,627	189,627	189,627	179,278	224,222	27,021	191,285	127,278	191,285	127,278	860	62,989	199	829
	temperature	°C	348.8	421.1	359.0	469.4	439.7	468.9	377.5	474.5	585.0	365.9	584.5	280.5	154.8	154.8	159.9	155.6	154.8	212.9	236.0	348.8
	pressure	bar	162.82	154.96	29.74	28.29	28.29	147.10	147.10	139.24	131.38	29.74	26.84	5.11	5.41	5.41	209.98	35.53	5.41	34.08	31.19	162.82
	enthalpy	kJ/kg	2,571.8	3,046.8	3,137.7	3,390.3	3,323.8	3,222.5	2,882.1	3,251.5	3,560.9	3,153.8	3,650.2	3,023.9	653.0	653.0	687.5	658.1	2,751.6	911.4	1,018.6	1,660.9
60% (2 × 60%)	mass flow	kg/h	147,558	147,558	202,935	202,935	207,676	147,558	175,283	175,283	175,283	165,727	207,676	24,287	176,773	121,927	176,773	121,927	792	58,355	188	745
	temperature	°C	344.0	425.4	362.0	469.3	441.3	472.8	363.1	467.3	584.9	370.4	584.5	279.3	154.8	154.8	159.7	155.5	154.8	211.3	232.4	344.0
	pressure	bar	153.48	145.62	27.79	26.34	26.34	137.76	137.76	129.90	122.04	27.79	24.89	5.11	5.41	5.41	200.64	33.58	5.41	32.13	29.23	153.48
	enthalpy	kJ/kg	2,600.7	3,083.2	3,148.7	3,392.7	3,330.3	3,248.6	2,843.3	3,244.7	3,569.1	3,168.1	3,651.8	3,021.5	653.0	653.0	685.9	657.7	2,751.6	903.9	1,001.6	1,623.9
50% (1 × 100%)	mass flow	kg/h	220,202	220,202	272,471	272,471	272,553	220,202	238,271	238,271	238,271	225,141	272,553	22,960	239,377	135,897	239,377	135,897	1,018	76,984	238	1,107
	temperature	°C	322.2	439.5	379.3	486.6	486.2	489.4	415.9	510.4	584.9	394.6	584.5	266.9	154.8	154.8	158.8	155.3	154.8	198.4	215.3	322.2
	pressure	bar	116.20	108.34	19.73	18.28	18.28	100.48	100.48	92.62	84.76	19.73	16.84	5.11	5.41	5.41	163.36	25.52	5.41	24.08	21.18	116.20
	enthalpy	kJ/kg	2,693.7	3,198.9	3,203.2	3,440.6	3,439.7	3,346.9	3,144.6	3,410.5	3,602.1	3,236.7	3,658.5	2,995.8	653.0	653.0	679.6	656.4	2,751.6	845.7	922.0	1,475.9
40% (1 × 80%)	mass flow	kg/h	180,323	180,323	245,676	245,676	250,514	180,323	214,579	214,579	214,579	202,781	250,514	19,421	216,400	132,396	216,400	132,396	928	68,726	217	911
	temperature	°C	316.7	438.4	383.1	476.6	452.1	483.7	341.6	468.5	584.9	400.0	584.5	265.1	154.8	154.8	158.6	155.3	154.8	196.5	211.2	316.7
	pressure	bar	108.06	100.20	18.07	16.63	16.63	92.34	92.34	84.48	76.62	18.07	15.18	5.11	5.41	5.41	155.22	23.87	5.41	22.42	19.52	108.06
	enthalpy	kJ/kg	2,710.2	3,209.9	3,214.4	3,420.6	3,367.2	3,342.7	2,917.4	3,314.4	3,609.0	3,251.4	3,660.0	2,992.0	653.0	653.0	678.3	656.1	2,751.6	837.1	903.0	1,442.2
30% (1 × 60%)	mass flow	kg/h	150,684	150,684	212,506	212,506	216,021	150,684	185,574	185,574	185,574	175,386	216,021	15,277	187,096	120,612	187,096	120,612	792	58,266	187	761
	temperature	°C	309.6	441.5	389.3	475.3	454.6	483.7	316.2	457.5	584.9	408.6	584.5	260.8	154.8	154.8	158.3	155.2	154.8	193.9	205.7	309.6
	pressure	bar	98.08	90.22	16.03	14.58	14.58	82.36	82.36	74.50	66.64	16.03	13.13	5.11	5.41	5.41	145.24	21.82	5.41	20.37	17.48	98.08
	enthalpy	kJ/kg	2,728.9	3,234.9	3,231.4	3,420.1	3,375.2	3,355.7	2,852.0	3,300.4	3,617.5	3,273.4	3,661.7	2,983.2	653.0	653.0	676.6	655.8	2,751.6	825.1	878.0	1,399.5
25% (1 × 50%)	mass flow	kg/h	165,338	165,338	189,988	189,988	189,988	165,338	165,338	165,338	165,338	156,286	189,988	14,752	167,008	108,156	167,008	108,156	693	49,324	170	835
	temperature	°C	303.5	454.8	386.2	499.8	499.8	504.0	504.0	542.4	574.1	406.3	569.3	252.2	154.8	154.8	158.1	155.2	154.8	192.3	201.1	303.5
	pressure	bar	90.21	82.35	14.45	13.01	13.01	74.49	74.49	66.63	58.77	14.45	11.56	5.11	5.41	5.41	137.37	20.25	5.41	18.80	15.90	90.21
	enthalpy	kJ/kg	2,742.5	3,282.2	3,227.5	3,475.3	3,475.3	3,415.7	3,415.7	3,516.7	3,599.0	3,270.8	3,629.2	2,965.3	653.0	653.0	675.2	655.5	2,751.6	818.2	857.3	1,364.6

Table 15: Stream tables for NGCC, max DAC, streams and water streams (continued)

	stream number		142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161
	description		**combined blowdown from both HRSGs**	**combined main steam from both HRSGs**	**combined hot reheat steam from both HRSGs**	**combined cold reheat to both HRSGs**	**combined LP steam from both HRSGs**	**HP turbine valve leak to SSR**	**HP turbine valve leak to hot reheat**	**HP turbine shaft leak to IP turbine**	**HP turbine LP end shaft leak to SSR**	**HP turbine LP end shaft leak to LP steam**	**HP turbine exhaust**	**LP turbine LP end shaft leak to SSR**	**IP turbine exhaust**	**combined steam to SSR**	**condensed DAC steam from regen**	**cooled blowdown to drain**	**condensate from SSR**	**BFW from DAC feedwater pump**	**steam to reclaim after pressure letdown**	**steam to reclaim after spray**
load	phase		**liquid**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**liquid**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	2,758	461,220	523,727	436,116	68,238	398	1,576	14,560	2,927	2,798	438,960	1,678	538,186	5,003	220,055	2,758	5,003	440,111	2,691	3,065
	temperature	°C	238.5	584.2	584.2	355.6	281.5	537.7	537.7	547.2	332.6	332.6	355.6	424.9	424.9	379.2	26.7	53.2	184.9	122.3	342.4	215.6
	pressure	bar	32.58	155.72	31.70	35.27	5.11	35.27	35.27	125.96	11.55	11.55	35.27	11.55	11.55	11.55	1.01	32.24	11.21	2.14	21.30	21.30
	enthalpy	kJ/kg	1,657.6	3,536.6	3,645.4	3,117.8	3,026.1	3,536.6	3,536.6	3,468.1	3,117.8	3,117.8	3,117.8	3,315.2	3,315.2	3,217.3	111.9	225.4	784.9	513.7	3,117.8	2,799.6
90% (2 × 90%)	mass flow	kg/h	2,576	438,515	499,182	414,652	65,547	381	1,501	13,875	2,908	2,558	417,292	1,665	512,893	4,954	214,903	2,576	4,954	429,806	2,498	2,856
	temperature	°C	238.0	584.6	584.5	358.3	280.1	540.2	540.2	547.8	337.0	337.0	358.3	431.5	431.5	383.8	26.7	53.4	184.8	122.3	346.7	215.6
	pressure	bar	32.29	148.78	30.27	33.81	5.11	33.81	33.81	120.34	11.52	11.52	33.81	11.52	11.52	11.52	1.01	31.95	11.18	2.14	21.30	21.30
	enthalpy	kJ/kg	1,625.1	3,543.9	3,647.3	3,127.4	3,023.1	3,543.9	3,543.9	3,475.7	3,127.4	3,127.4	3,127.4	3,329.5	3,329.5	3,227.3	111.9	226.2	784.4	513.7	3,127.4	2,799.6
80% (2 × 80%)	mass flow	kg/h	2,261	409,212	469,943	386,891	59,579	360	1,401	12,975	2,804	2,347	389,325	1,609	482,709	4,774	204,233	2,261	4,774	408,467	2,304	2,646
	temperature	°C	237.3	584.5	584.4	362.1	281.4	543.1	543.1	548.2	342.6	342.6	362.1	435.7	435.7	388.6	26.7	53.6	183.4	122.3	352.3	215.6
	pressure	bar	31.93	139.54	28.54	32.04	5.11	32.04	32.04	112.86	11.17	11.17	32.04	11.17	11.17	11.17	1.01	31.58	10.83	2.14	21.30	21.30
	enthalpy	kJ/kg	1,576.5	3,552.1	3,648.6	3,140.1	3,025.8	3,552.1	3,552.1	3,484.3	3,140.1	3,140.1	3,140.1	3,338.9	3,338.9	3,238.2	111.9	226.9	778.1	513.7	3,140.1	2,799.6
70% (2 × 70%)	mass flow	kg/h	2,057	379,254	437,532	358,557	54,042	336	1,300	12,056	2,707	2,094	360,760	1,555	449,333	4,598	193,511	2,057	4,598	387,022	2,085	2,407
	temperature	°C	236.6	584.5	584.4	366.2	280.5	546.2	546.2	548.8	348.7	348.7	366.2	441.9	441.9	394.3	26.7	53.8	182.0	122.3	358.4	215.6
	pressure	bar	31.50	130.06	26.57	30.04	5.11	30.04	30.04	105.20	10.85	10.85	30.04	10.85	10.85	10.85	1.01	31.15	10.50	2.14	21.30	21.30
	enthalpy	kJ/kg	1,536.4	3,560.9	3,650.2	3,153.8	3,023.9	3,560.9	3,560.9	3,493.6	3,153.8	3,153.8	3,153.8	3,352.6	3,352.6	3,250.8	111.9	227.8	772.1	513.7	3,153.8	2,799.6
60% (2 × 60%)	mass flow	kg/h	1,866	350,565	405,871	331,453	48,574	314	1,203	11,166	2,632	1,827	333,424	1,512	416,728	4,458	183,657	1,866	4,458	367,314	1,865	2,165
	temperature	°C	235.8	584.5	584.4	370.7	279.3	549.0	549.0	549.3	355.2	355.2	370.7	449.9	449.9	400.7	26.7	54.1	181.0	122.3	364.8	215.6
	pressure	bar	31.05	120.82	24.64	28.07	5.11	28.07	28.07	97.73	10.61	10.61	28.07	10.61	10.61	10.61	1.01	30.71	10.26	2.14	21.30	21.30
	enthalpy	kJ/kg	1,498.6	3,569.1	3,651.8	3,168.1	3,021.5	3,569.1	3,569.1	3,502.6	3,168.1	3,168.1	3,168.1	3,370.1	3,370.1	3,264.8	111.9	229.1	767.7	513.7	3,168.1	2,799.6
50% (1 × 100%)	mass flow	kg/h	1,344	238,271	272,471	225,141	22,960	221	821	7,658	1,585	1,495	226,490	942	280,009	2,747	112,678	1,344	2,747	225,357	1,276	1,521
	temperature	°C	231.8	584.6	584.4	394.7	266.9	560.4	560.4	553.0	384.2	384.2	394.7	437.8	437.8	416.6	26.7	54.1	160.2	122.3	394.7	212.2
	pressure	bar	28.93	83.91	16.67	19.93	5.11	19.93	19.93	67.87	6.56	6.56	19.93	6.56	6.56	6.56	1.01	28.58	6.22	2.14	19.93	19.93
	enthalpy	kJ/kg	2,755.7	3,602.1	3,658.5	3,236.7	2,995.8	3,602.1	3,602.1	3,540.7	3,236.7	3,236.7	3,236.7	3,349.7	3,349.7	3,304.8	111.9	228.8	676.6	513.7	3,236.7	2,798.3
40% (1 × 80%)	mass flow	kg/h	1,127	214,579	245,676	202,781	19,421	202	738	6,905	1,532	1,274	203,928	908	252,412	2,641	105,154	1,127	2,641	210,308	1,085	1,300
	temperature	°C	230.9	584.6	584.5	400.2	265.1	562.8	562.8	553.6	391.1	391.1	400.2	448.8	448.8	423.9	26.7	54.5	159.0	122.3	400.2	207.8
	pressure	bar	28.41	75.86	15.03	18.26	5.11	18.26	18.26	61.36	6.38	6.38	18.26	6.38	6.38	6.38	1.01	28.07	6.03	2.14	18.26	18.26
	enthalpy	kJ/kg	2,677.2	3,609.0	3,660.0	3,251.4	2,992.0	3,609.0	3,609.0	3,548.5	3,251.4	3,251.4	3,251.4	3,373.4	3,373.4	3,320.6	111.9	230.6	671.4	513.7	3,251.4	2,796.3
30% (1 × 60%)	mass flow	kg/h	949	185,574	212,506	175,386	15,277	178	637	5,986	1,434	1,034	176,305	849	218,281	2,461	94,586	949	2,461	189,173	868	1,051
	temperature	°C	229.5	584.6	584.5	408.7	260.8	565.9	565.9	554.7	401.3	401.3	408.7	461.8	461.8	434.0	26.7	55.1	156.7	122.3	408.7	201.9
	pressure	bar	27.73	65.98	13.00	16.19	5.11	16.19	16.19	53.36	6.02	6.02	16.19	6.02	6.02	6.02	1.01	27.39	5.67	2.14	16.19	16.19
	enthalpy	kJ/kg	2,592.9	3,617.5	3,661.7	3,273.4	2,983.2	3,617.5	3,617.5	3,558.6	3,273.4	3,273.4	3,273.4	3,401.4	3,401.4	3,342.5	111.9	233.0	661.1	513.7	3,273.4	2,793.2
25% (1 × 50%)	mass flow	kg/h	1,005	165,338	189,988	156,286	14,752	162	561	5,304	1,291	937	157,085	768	195,085	2,221	85,043	1,005	2,221	170,086	755	913
	temperature	°C	228.4	573.9	569.2	406.4	252.2	556.9	556.9	545.0	399.6	399.6	406.4	451.5	451.5	429.0	26.7	55.1	152.3	122.3	406.4	197.0
	pressure	bar	27.16	58.18	11.44	14.60	5.11	14.60	14.60	47.06	5.41	5.41	14.60	5.41	5.41	5.41	1.01	26.82	5.07	2.14	14.60	14.60
	enthalpy	kJ/kg	2,557.4	3,599.0	3,629.2	3,270.8	2,965.3	3,599.0	3,599.0	3,542.0	3,270.8	3,270.8	3,270.8	3,380.4	3,380.4	3,332.6	111.9	233.1	642.4	513.7	3,270.8	2,790.2

Table 15: Stream tables for NGCC, max DAC, streams and water streams (continued)

	stream number		162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
	description		**spray water to reclaim attemp.**	**condensate return from reclaim**	**steam to CO_2 drying after pressure letdown**	**spray water to CO_2 drying attemp.**	**steam to CO_2 drying after spray**	**condensate return from CO_2 drying**	**combined condensate from reclaim and CO_2 drying**	**steam to PCC reboiler after pressure letdown**	**steam to PCC reboiler after desuperheat**	**condensate from PCC reboiler**	**condensate entering condensate cooler, HX-3**	**condensate exiting condensate cooler, HX-3**	**condensate exiting LP steam condenser HX-7**	**attemp. spray pump discharge**	**from IP turbine exhaust to LP turbine or DAC steam generator**	**LP steam from HRSG to HX-7**	**LP steam from HRSGs to LP turbine**	**steam exhausting from first LP turbine**	**steam entering second LP turbine**	**LP steam to HX-7**
load	phase		**liquid**	**liquid**	**vapor**	**liquid**	**vapor**	**liquid**	**liquid**	**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**liquid**	**liquid**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	374	3,065	153	22	174	174	3,239	335,719	335,719	335,719	602,619	602,619	263,660	395	205,265	58,396	0	0	0	263,660
	temperature	°C	120.6	214.8	338.2	120.6	204.4	203.4	203.4	420.7	152.3	149.7	149.7	120.0	150.0	38.5	424.4	281.5	0	0	0	389.6
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	11.55	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	919.5	3,117.8	507.9	2,794.6	867.8	916.8	3,315.2	2,748.7	631.0	633.1	504.0	632.4	507.7	3,314.2	3,026.1	0	0	0	3,250.4
90% (2 × 90%)	mass flow	kg/h	357	2,856	142	21	162	162	3,018	312,823	312,823	312,823	574,387	574,387	258,546	378	202,628	55,918	0	0	0	258,546
	temperature	°C	120.6	214.8	342.5	120.6	204.4	203.4	203.4	427.5	152.3	149.7	149.7	120.0	150.0	38.5	431.1	280.1	0	0	0	395.4
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	11.52	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	919.5	3,127.4	507.9	2,794.6	867.8	916.8	3,329.5	2,748.7	631.0	633.1	504.0	632.4	507.7	3,328.5	3,023.1	0	0	0	3,262.4
80% (2 × 80%)	mass flow	kg/h	342	2,646	131	20	150	150	2,797	289,877	289,877	289,877	538,289	538,289	245,615	362	195,178	50,436	0	0	0	245,615
	temperature	°C	120.6	214.8	348.3	120.6	204.4	203.4	203.4	432.0	152.3	149.7	149.7	120.0	150.0	38.5	435.2	281.4	0	0	0	400.8
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	11.17	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	919.5	3,140.1	507.9	2,794.6	867.8	916.8	3,338.9	2,748.7	631.0	633.1	504.0	632.4	507.7	3,338.0	3,025.8	0	0	0	3,273.9
70% (2 × 70%)	mass flow	kg/h	322	2,407	118	19	137	137	2,544	263,724	263,724	263,724	499,351	499,351	233,082	341	187,702	45,380	0	0	0	233,082
	temperature	°C	120.6	214.8	354.5	120.6	204.4	203.4	203.4	438.4	152.3	149.7	149.7	120.0	150.0	38.5	441.4	280.5	0	0	0	407.5
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	10.85	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	919.5	3,153.8	507.9	2,794.6	867.8	916.8	3,352.6	2,748.7	631.0	633.1	504.0	632.4	507.7	3,351.7	3,023.9	0	0	0	3,287.9
60% (2 × 60%)	mass flow	kg/h	300	2,165	106	17	123	123	2,288	237,140	237,140	237,140	461,186	461,186	221,759	317	181,414	40,344	0	0	0	221,759
	temperature	°C	120.6	214.8	361.1	120.6	204.4	203.4	203.4	446.7	152.3	149.7	149.7	120.0	150.0	38.5	449.5	279.3	0	0	0	416.1
	pressure	bar	27.59	20.96	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	10.61	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	919.5	3,168.1	507.9	2,794.6	867.8	916.8	3,370.1	2,748.7	631.0	633.1	504.0	632.4	507.7	3,369.2	3,021.5	0	0	0	3,306.0
50% (1 × 100%)	mass flow	kg/h	244	1,521	73	14	87	87	1,608	167,860	167,860	167,860	300,976	300,976	131,509	258	113,644	17,865	0	0	0	131,509
	temperature	°C	120.6	211.3	392.5	120.6	204.4	203.4	203.4	437.1	152.3	149.7	149.7	120.0	150.0	38.5	437.5	266.9	0	0	0	413.8
	pressure	bar	27.59	19.59	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	6.56	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	903.8	3,236.7	507.9	2,794.6	867.8	901.8	3,349.7	2,748.7	631.0	633.0	504.0	632.4	507.7	3,349.1	2,995.8	0	0	0	3,301.1
40% (1 × 80%)	mass flow	kg/h	216	1,300	63	13	75	75	1,376	144,939	144,939	144,939	269,721	269,721	123,407	228	108,747	14,660	0	0	0	123,407
	temperature	°C	120.6	206.9	399.2	120.6	204.4	203.4	203.4	448.2	152.3	149.7	149.7	120.0	150.0	38.5	448.5	265.1	0	0	0	426.4
	pressure	bar	27.59	17.91	17.03	27.59	17.03	16.69	16.69	5.41	5.07	4.72	4.72	4.38	4.76	27.58	6.38	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	883.5	3,251.4	507.9	2,794.6	867.8	882.7	3,373.4	2,748.7	631.0	632.9	504.0	632.4	507.7	3,372.8	2,992.0	0	0	0	3,327.6
30% (1 × 60%)	mass flow	kg/h	182	1,051	51	11	61	61	1,112	118,570	118,570	118,570	231,406	231,406	111,724	193	100,744	10,980	0	0	0	111,724
	temperature	°C	120.6	200.9	408.7	120.6	204.4	200.9	200.9	461.4	152.3	149.7	149.7	120.0	150.0	38.5	461.5	260.8	0	0	0	441.6
	pressure	bar	27.59	15.85	16.19	27.59	16.19	15.85	15.85	5.41	5.07	4.72	4.72	4.38	4.76	27.58	6.02	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	856.5	3,273.4	507.9	2,793.2	856.5	856.5	3,401.4	2,748.7	631.0	632.7	504.0	632.4	507.7	3,400.8	2,983.2	0	0	0	3,359.8
25% (1 × 50%)	mass flow	kg/h	159	913	44	9	53	53	967	104,124	104,124	104,124	207,852	207,852	102,761	168	91,898	10,864	0	0	0	102,761
	temperature	°C	120.6	195.9	406.4	120.6	204.4	195.9	195.9	451.5	152.3	149.7	149.7	120.0	150.0	38.5	451.3	252.2	0	0	0	430.4
	pressure	bar	27.59	14.26	14.60	27.59	14.60	14.26	14.26	5.41	5.07	4.72	4.72	4.38	4.76	27.58	5.41	5.11	0	0	0	5.11
	enthalpy	kJ/kg	507.9	833.9	3,270.8	507.9	2,790.2	833.9	833.9	3,380.4	2,748.7	631.0	632.6	504.0	632.4	507.7	3,379.9	2,965.3	0	0	0	3,336.0

Table 15: Stream tables for NGCC, max DAC, streams and water streams (continued)

	stream number		**182**	**183**	**184**	**185**	**186**	**187**	**188**	**189**	**190**	**191**	**192**	**193**	**194**	**195**	**196**	**197**	**198**
	description		**DAC steam lost to atmosphere during regen**	**steam from IP turbine to LP turbine**	**condensate entering HX-8**	**condensate exiting HX-9**	**makeup water for HRSG**	**exhaust from LP turbine 2 to HX-6**	**condensate exiting from HX-6**	**condensate from condensate pump to HRSGs**	**condensate from SSR**	**steam to DAC**	**condensate to one HRSG LP economizer**	**makeup water to DAC supply**	**condensate from DAc condensate supply pump**	**LP steam to DAC decarbonator**	**condensate to DAC decarbonator**	**vent from DAC decarbonator**	**condensate between HX-8 and HX-9**
load	phase		**vapor**	**vapor**	**liquid**	**liquid**	**liquid**	**mixed**	**liquid**	**liquid**	**liquid**	**vapor**	**liquid**	**liquid**	**liquid**	**vapor**	**liquid**	**vapor**	**liquid**
100% (2 × 100%)	mass flow	kg/h	220,055	0	602,223	602,223	14,637	0	0	621,863	621,863	440,111	340,348	211,093	431,148	9,843	431,148	880	602,223
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	43.2	110.0	46.1	26.7	26.7	281.5	110.0	122.3	60.6
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	181.4	2,691.1	193.5	111.9	112.2	3,026.1	461.4	2,709.3	254.0
90% (2 × 90%)	mass flow	kg/h	214,903	0	574,010	574,010	14,157	0	0	593,120	593,120	429,806	323,967	206,140	421,043	9,622	421,043	860	574,010
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	43.4	110.0	46.2	26.7	26.7	280.1	110.0	122.3	59.1
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	182.2	2,691.1	193.9	111.9	112.2	3,023.1	461.4	2,709.3	247.8
80% (2 × 80%)	mass flow	kg/h	204,234	0	537,927	537,927	13,261	0	0	555,951	555,951	408,467	303,373	195,915	400,148	9,136	400,148	817	537,927
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	43.6	110.0	46.2	26.7	26.7	281.4	110.0	122.3	58.3
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	182.9	2,691.1	194.0	111.9	112.2	3,025.8	461.4	2,709.3	244.2
70% (2 × 70%)	mass flow	kg/h	193,511	0	499,010	499,010	12,440	0	0	516,048	516,048	387,022	281,127	185,623	379,134	8,662	379,134	774	499,010
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	43.8	110.0	46.3	26.7	26.7	280.5	110.0	122.3	56.9
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	183.9	2,691.1	194.5	111.9	112.2	3,023.9	461.4	2,709.3	238.7
60% (2 × 60%)	mass flow	kg/h	183,657	0	460,869	460,869	11,680	0	0	477,007	477,007	367,314	259,274	176,164	359,820	8,228	359,820	735	460,869
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	44.1	110.0	46.5	26.7	26.7	279.3	110.0	122.3	55.2
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	185.1	2,691.1	195.3	111.9	112.2	3,021.5	461.4	2,709.3	231.3
50% (1 × 100%)	mass flow	kg/h	112,679	0	300,718	300,718	7,458	0	0	310,921	310,921	225,357	340,337	108,035	220,713	5,095	220,713	451	300,718
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	44.1	110.0	47.9	26.7	26.7	266.9	110.0	122.3	59.1
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	185.0	2,691.1	201.0	111.9	112.2	2,995.8	461.4	2,709.3	247.7
40% (1 × 80%)	mass flow	kg/h	105,154	0	269,493	269,493	6,817	0	0	278,951	278,951	210,308	304,349	100,814	205,967	4,761	205,967	421	269,493
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	44.5	110.0	48.0	26.7	26.7	265.1	110.0	122.3	56.6
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	186.9	2,691.1	201.6	111.9	112.2	2,992.0	461.4	2,709.3	237.1
30% (1 × 60%)	mass flow	kg/h	94,586	0	231,213	231,213	6,038	0	0	239,712	239,712	189,173	260,483	90,669	185,255	4,296	185,255	378	231,213
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	45.1	110.0	48.4	26.7	26.7	260.8	110.0	122.3	53.5
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	189.3	2,691.1	203.1	111.9	112.2	2,983.2	461.4	2,709.3	224.2
25% (1 × 50%)	mass flow	kg/h	85,043	0	207,684	207,684	5,586	0	0	215,491	215,491	170,086	230,773	81,495	166,538	3,888	166,538	340	207,684
	temperature	°C	100.0	0	120.0	37.8	26.7	0	0	38.5	45.1	110.0	48.6	26.7	26.7	252.2	110.0	122.3	53.4
	pressure	bar	1.01	0	4.38	3.69	6.89	0	0	6.69	6.34	1.43	6.00	1.01	2.90	5.11	2.55	2.14	4.03
	enthalpy	kJ/kg	2,675.5	0	504.0	158.6	112.4	0	0	161.8	189.5	2,691.1	204.0	111.9	112.2	2,965.3	461.4	2,709.3	224.0

Table 16: Stream tables for NGCC, max DAC, gas streams

	stream number		**201**	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	**213**	**214**	**215**	**216**	**217**	**218**	**219**	**220**	**221**	**222**
	description		**total flue gas entering HPSH4**	**total flue gas entering IPSH3**	**total flue gas entering HPSH3**	**total flue gas entering HPSH2**	**total flue gas entering IPSH2**	**total flue gas entering HPSH1**	**total flue gas entering HPEVAP**	**total flue gas entering HPEC5**	**total flue gas entering IPSH1**	**total flue gas entering HPEC4**	**total flue gas entering HPEC3**	**total flue gas entering LPSH**	**total flue gas entering IPEVAP**	**total flue gas entering IPEC2**	**total flue gas entering HPEC2**	**total flue gas entering IPEC1**	**total flue gas entering HPEC1**	**total flue gas entering LPEVAP**	**total flue gas entering LPECON**	**total flue gas exiting stack**	**total ambient air entering gas turbine**	**total natural gas entering gas turbine**
load	phase		**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**
100% (2 × 100%)	mass flow	kg/h	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,927,395	3,834,106	93,272
	temperature	°C	625.0	605.9	577.2	555.0	533.7	499.8	452.2	369.4	347.1	341.6	334.3	294.2	289.8	253.1	250.6	238.4	228.8	200.6	163.2	88.1	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
90% (2 × 90%)	mass flow	kg/h	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,715,315	3,628,398	86,901
	temperature	°C	628.2	607.0	576.6	551.2	531.2	497.7	450.5	366.0	344.9	339.3	332.5	292.6	288.1	250.6	248.1	236.6	227.1	199.7	162.8	87.2	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
80% (2 × 80%)	mass flow	kg/h	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,419,583	3,339,037	80,531
	temperature	°C	644.3	613.8	573.6	538.1	520.6	488.9	444.5	361.0	343.0	337.1	331.3	292.6	288.2	247.8	245.3	235.3	225.6	199.8	162.4	85.0	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
70% (2 × 70%)	mass flow	kg/h	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,169,408	3,096,138	73,256
	temperature	°C	644.3	612.3	572.2	533.5	517.4	486.5	442.5	356.1	339.8	333.8	328.5	290.3	285.9	244.1	241.8	232.7	223.1	198.5	161.8	84.6	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
60% (2 × 60)	mass flow	kg/h	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,921,982	2,856,110	65,859
	temperature	°C	644.3	610.7	570.9	528.7	514.0	483.9	440.4	351.0	336.3	330.2	325.5	287.7	283.5	240.5	238.2	229.8	220.5	197.1	161.3	84.3	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
50% (1 × 100%)	mass flow	kg/h	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,963,697	1,917,053	46,636
	temperature	°C	625.0	604.9	578.5	550.3	535.7	506.7	456.2	334.8	319.1	313.7	307.8	270.4	267.7	225.2	223.3	215.2	208.1	188.4	161.0	88.5	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
40% (1 × 80%)	mass flow	kg/h	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,709,791	1,669.518	40,265
	temperature	°C	644.3	612.4	575.1	531.4	519.1	492.8	445.8	327.6	314.7	309.1	304.2	267.7	265.1	220.6	218.8	212.0	205.1	186.9	160.3	85.6	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
30% (1 × 60%)	mass flow	kg/h	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,460,991	1,428,055	32,930
	temperature	°C	644.3	609.5	572.7	522.7	511.7	487.4	440.7	319.3	308.1	302.5	298.3	262.2	260.0	214.4	212.8	206.9	200.4	184.0	159.3	84.9	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6
25% (1 × 50%)	mass flow	kg/h	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,443,236	1,414,420	28,891
	temperature	°C	587.7	579.5	561.8	551.7	538.3	509.5	454.5	314.5	301.1	296.0	290.7	253.4	251.4	209.1	207.8	201.5	196.2	180.3	158.7	90.7	15.0	26.7
	pressure	bar	1.08	1.08	1.07	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.01	1.0	29.6

Table 17: Stream tables for PCC and DAC

load	stream number		170	171	220	301	302	401	505	159	191	501	502	503	504	505	506	507	508	509	601	602
	description		**steam to PCC reboiler HX-4**	**condensate from PCC reboiler HX-4**	**flue gas entering PCC**	**treated flue gas exiting PCC**	**CO_2/H_2O exiting PCC**	**PCC product entering pipeline**	**vent gas exiting DAC deaerator**	**DAC condensate BFW**	**DAC steam to regenerator**	**ambient air entering DAC**	**treated air exiting DAC**	**DAC regenerator exit**	**CO_2 entering DAC compression/purification**	**vent gas exiting DAC deaerator**	**LP steam to DAC deaerator**	**recovered water from DAC deaerator**	**DAC makeup water**	**water loss to atmposhere**	**overhead vent from DAC distillation**	**DAC CO_2 entering pipeline**
load	phase		**vapor**	**liquid**	**vapor**	**vapor**	**vapor**	**supercritical**	**vapor**	**liquid**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**vapor**	**liquid**	**liquid**	**vapor**	**vapor**	**supercritical**
100% (2 × 100%) min DAC	mass flow	kg/h	335,719	335,719	3,927,395	3,538,450	251,877	250,526	258	107,548	107,548	106,888,001	106,864,612	88,751	35,527	258	2,051	53,225	52,531	53,774	1,745	33,180
	molar flow	kg mol/h	18,651	18,651	138,679	125,405	5,771	5,695	13	5,975	5,975	3,690,285	3,689,525	3,791	835	13	114	2,955	2,918	2,987	48	754
	temperature	°C	152.3	149.7	89.2	30.6	30.0	30.0	122.2	122.3	110.0	25	25	101.7	30.0	122.2	424.9	30.0	15.0		10.0	30.0
	pressure	bar	5.07	4.72	1.01	1.02	1.99	152.68	2.14	2.14	1.43	1.02	1.01	1.17	1.03	2.14	11.55	1.03	1.03	1.03	22.75	152.68
100% (2 × 100%) max DAC	mass flow	kg/h	335,719	335,719	3,927,395	3,538,450	251,877	250,526	1,085	440,111	440,111	430,326,246	430,232,080	363,187	145,375	1,085	8,613	217,814	214,769	220,055	7,140	135,774
	molar flow	kg mol/h	18,651	18,651	138,679	125,405	5,771	5,695	53	24,451	24,451	14,856,921	14,853,860	15,512	3,418	53	479	12,094	11,932	12,225	196	3,086
	temperature	°C	152.3	149.7	88.2	30.6	30.0	30.0	122.2	122.3	110.0	25	25	101.7	30.0	122.2	424.9	30.0	15.0	-17.8	10.0	30.0
	pressure	bar	5.07	4.72	1.01	1.02	1.99	152.68	2.14	2.14	1.43	1.02	1.01	1.17	1.03	2.14	11.55	1.03	1.03	1.03	22.75	152.68
25% (1 × 50%) max DAC	mass flow	kg/h	104,124	104,124	1,963,697	1,806,362	106,299	105,729	418	170,086	170,086	229,903,065	229,852,756	140,358	56,183	418	3,253	84,175	83,076	85,043	2,759	52,472
	molar flow	kg mol/h	5,785	5,785	69,144	63,916	2,435	2,404	20	9,449	9,449	7,937,354	7,935,718	5,995	1,321	20	181	4,674	4,615	4,725	76	1,193
	temperature	°C	152.3	149.7	88.5	30.6	30.0	30.0	122.2	122.3	110.0	25	25	101.7	30.0	122.2	451.4	30.0	15.0		10.0	30.0
	pressure	bar	5.07	4.72	1.01	1.02	1.99	152.68	2.14	2.14	1.43	1.02	1.01	1.17	1.03	2.14	5.41	1.03	1.03	1.03	22.75	152.68
composition at 100% Load	Ar	mol fraction	0.0000	0.0000	0.0088	0.0097	0.0000	0.0000	0.0000	0.000	0.000	0.0093	0.0093	0.0001	0.0003	0.0000	0.000	0.0000	0.000	0.000	0.000280301	0
	CO_2	mol fraction	0.0000	0.0000	0.0423	0.0014	0.9865	0.9995	0.0935	0.000	0.000	0.0004	0.0002	0.2055	0.9312	0.0935	0.000	0.0004	0.000	0.000	0.5	1
	H_2O	mol fraction	1.0000	1.0000	0.0935	0.0430	0.0135	0.0005	0.9065	1.000	1.000	0.0000	0.0000	0.7881	0.0400	0.9065	1.000	0.9996	1.000	1.000	0	0
	N_2	mol fraction	0.0000	0.0000	0.7407	0.8192	0.0000	0.0000	0.0000	0.000	0.000	0.7808	0.7810	0.0050	0.0225	0.0000	0.000	0.0000	0.000	0.000	0.394232064	0
	O_2	mol fraction	0.0000	0.0000	0.1146	0.1267	0.0000	0.0000	0.0000	0.000	0.000	0.2095	0.2095	0.0013	0.0060	0.0000	0.000	0.0000	0.000	0.000	0.105767936	1.00E-05
composition at 50% Load	Ar	mol fraction	0.0000	0.0000	0.0089	0.0096	0.0000	0.0000	0.0000	0.000	0.000	0.0093	0.0093	0.0001	0.0003	0.0000	0.000	0.0000	0.000	0.000	0.000280301	0
	CO_2	mol fraction	0.0000	0.0000	0.0358	0.0012	0.9865	0.9995	0.0930	0.000	0.000	0.0004	0.0002	0.2055	0.9312	0.0930	0.000	0.0004	0.000	0.000	0.5	1
	H_2O	mol fraction	1.0000	1.0000	0.0806	0.0430	0.0135	0.0005	0.9070	1.000	1.000	0.0000	0.0000	0.7881	0.0400	0.9070	1.000	0.9996	1.000	1.000	0	0
	N_2	mol fraction	0.0000	0.0000	0.7457	0.8068	0.0000	0.0000	0.0000	0.000	0.000	0.7808	0.7810	0.0050	0.0225	0.0000	0.000	0.0000	0.000	0.000	0.394232064	0
	O_2	mol fraction	0.0000	0.0000	0.1290	0.1395	0.0000	0.0000	0.0000	0.000	0.000	0.2095	0.2095	0.0013	0.0060	0.0000	0.000	0.0000	0.000	0.000	0.105767936	1.00E-05

5. Costing

5.1. NGCC & Steam System

The NGCC and the steam system costing is given in the following tables. Table 18 provides the capital cost of retrofitting the original NGCC steam system and Table 19 gives the capital cost of other steam-related equipment. Tables 20 and 21 calculate the fixed and variable O&M cost of the NGCC retrofit based on the O&M cost of the B31A case in [5].

Table 18: Steam system capital cost (the NGCC part)

equipment	type	design conditions	equipment cost	material cost	labor	bare erected cost	engineering, HO & fee	project contingency	total plant cost
IP turbine	steam turbine	48,755	$ 6,323,175	$ 219,398	$ 955,598	$ 7,498,171	$ 1,499,634	$ 1,349,671	$ 10,347,476
LP turbine 1	steam turbine	12,397	$ 1,607,802	$ 55,787	$ 242,981	$ 1,906,570	$ 381,314	$ 343,183	$ 2,631,067
LP turbine 2	steam turbine	52,599	$ 6,821,715	$ 236,696	$ 1,030,940	$ 8,089,350	$ 1,617,870	$ 1,456,083	$ 11,163,304
steam turbine piping	piping		$ 3,853,315	$ -	$ 1,564,076	$ 5,417,391	$ 1,083,478	$ 975,130	$ 7,476,000
HX-6 LP steam condenser	heat exchanger	571 MMBTU/h	$ 5,574,810	0	$ 2,763,755	$ 8,338,565	$ 1,667,713	$ 1,500,942	$ 11,507,220
cooling tower cells		31A has a cooling tower load of 1490 MMBTU/h. For the worst case 2298 MMBTU/h is needed. Assume this (2298-1490) 808 MMBTU/h is added to the existing cooling tower. Includes Tower (9.1) and Circ Water Auxiliaries (9.3)	$ 10,972,748		$ 2,476,345	$ 13,449,093	$ 2,689,819	$ 2,420,837	$ 18,559,748
circ. water pumps & Piping		31A has a cooling tower load of 1490 MMBTU/h. For the worst case 2298 MMBTU/h is needed. Assume that instead of a fully replacing the circ water pumps and piping, a separate circuit is taken from the cooling tower basin to supply the additional 808 MMBTU/h load. Includes Circ Water Pumps (9.2) and Circ Water Piping (9.4)	$ 721,371	$ 1,601,485	$ 1,494,119	$ 3,816,975	$ 763,395	$ 687,055	$ 5,267,425
total									$ 66,952,239

Table 19: Steam system capital cost (other equipment)

equipment identification	equipment type	basis	quantity	purchased equipment cost 2004	est. year	bare module cost factor	bare module cost	engineering, HO & fee	project contingency	total plant cost
DAC steam drum	horizontal drum	CS, low pressure, assume 6 ft dia, 24 ft long	1	$ 40,000	$ 59,620	3.25	$ 193,765	$ 38,753	$ 34,878	$ 267,396
HX-3 condensate cooler	single pass shell and tube heat exchanger	CS, low pressure, 10,815 ft$\hat{2}$ surface	2	$ 120,000	$ 178,860	3.25	$ 581,295	$ 116,259	$ 104,633	$ 802,187
HX-5 PCC steam desuperheater	single pass shell and tube heat exchanger	high inlet temperature, low pressure, 5407 ft$\hat{2}$ surface	1	$ 35,000	$ 52,168	7	$ 365,173	$ 73,035	$ 65,731	$ 503,938
HX-7 LP steam condenser	single pass shell and tube heat exchanger	high inlet temperature, low pressure, 16222 ft$\hat{2}$ surface	3	$ 240,000	$ 357,720	7	$ 2,504,040	$ 500,808	$ 450,727	$ 3,455,575
DAC condensate collection drum	vertical drum	CS, low pressure, 12 ft diameter, 36 ft tall (tan/tan). Clad due to pH	1	$ 65,000	$ 96,883	7	$ 678,178	$ 135,636	$ 122,072	$ 935,885
DAC condensate supply pump decarbonator	centrifugal pump	Centrifugal pump, 35 kW	2	32,000	$ 47,696	4	$ 190,784	$ 38,157	$ 34,341	$ 263,282
DAC feedwater pump	centrifugal pump	Centrifugal pump, 35 kW	2	32,000	$ 47,696	4	$ 190,784	$ 38,157	$ 34,341	$ 263,282
HX-8 DAC preheater	single pass shell and tube heat exchanger	CS, low pressure, 5910 ft$\hat{2}$ surface	2	$ 80,000	$ 119,240	3.25	$ 387,530	$ 77,506	$ 69,755	$ 534,791
HX-9 cooler	single pass shell and tube heat exchanger	CS, low pressure, 5737 ft$\hat{2}$ surface	2	$ 80,000	$ 119,240	3.25	$ 387,530	$ 77,506	$ 69,755	$ 534,791
attemperator spray pump		centrifugal pump, 0.5 kW	2	6,000	$ 8,943	3.3	$ 29,512	$ 5,902	$ 5,312	$ 40,726
total										$ 7,334,458

Table 20: NGCC fixed O&M cost

item	original	with retrofit	difference	notes
annual operating labor	$ 2,192,190	$ 3,069,066	$ 876,876	Assuming two operators per shift for new equipment associated with DAC
maintenance labor	$ 4,308,976	$ 4,544,576	$ 235,600	The Original is 0.76% of the capital cost (Exhibit 5-17). The project adds $74 million in capital. But $43 million is for equipment already in previous scope (steam turbine/condenser). $31 million is for new (DAC) equipment. Multiply this times 0.76% and add it to original.
administrative and support labor	$ 1,625,292	$ 1,625,292	$ -	Assume no change
property taxes and insurance	$ 11,339,411	$ 11,959,411	$ 620,000	The Original is 2% of the capital cost (Exhibit 5-17). $31 million is added for new (DAC) equipment. Multiply this times 2% and add it to original.
total	$ 19,465,869	$ 21,198,345	$ 1,732,476	

Table 21: NGCC variable O&M cost

item	initial fill	per day	per unit	initial fill cost	original	with retrofit	difference	notes
maintenance material					$ 6,463,464	$ 6,819,964	$ 356,500	The Original is 1.15% of the capital cost (Exhibit 5-17). $31 million is added for new (DAC) equipment. Multiply this times 2% and add it to original.
consumables								
original water (/1000 gallons)	0	2090	$ 1.90	$ -	$ 1,232,003			
new water (/1000 gallons)		4156	$ 1.90			$ 2,449,996	$ 1,217,993	
makeup and wastewater treatment chemicals (ton)	0	6.22	$ 550.00	0	$ 1,061,365			
new chemicals (ton)		12.4	$ 550.00	0		$ 2,110,661	$ 1,049,296	
ammonia 19 wt%, ton (no change)	0	3.45	$ 300	0	$ 321,109		$ -	
SCR catalyst ft3̂ (no change)	5649	3.1	$ 150	$ 847,350	$ 144,266		$ -	
waste disposal								
SCR catalyst, ft3̂ (no change)	$ -	3.1	$ 2.50	0	$ 2,404		$ -	
total					$ 9,224,611		$ 2,623,789	

5.2. PCC and PCC Compression

The team used the following methodology to develop PCC and PCC compression costs for the 97% capture requirements for this project:

- *Cost model.* The team started with the PCC and PCC Compression costs from Case B13B in [5]. Case B31B is based on Shell Cansolv's carbon capture system for 90% CO_2 capture for a natural gas combined cycle power plant. The team adjusted this case to 97% CO_2 capture, as described in the following bullets.
- *Steam requirement.* The team used published modeling data from MEA and piperazine to guide selection of heat duties for 97% capture. The specific reboiler steam requirement (as GJ/tonne or MMBtu/tonne CO_2) was assumed to be constant between 90% capture and 97% capture; likewise for the reclaimer and dryer duties.
- *Power requirement.* The CO_2 capture auxiliaries and the CO_2 compression power were scaled linearly with the CO_2 capture rate.
- *Capital cost of PCC.* The capital cost of the B31B PCC was scaled from 90% CO_2 capture to 97% CO_2 capture using a cost scaling relationship that was derived from [2]. The paper developed cost estimates for CO_2 capture for MEA-based systems for capture rates ranging from 90% to 99.04%. Since Cansolv is also an amine-based solvent system, the team used these data as a first approximation to estimate the capital cost associated with higher CO_2 capture rate. For the PCC equipment, the cost scaled to the ratio of the CO_2 capture rates, raised to the 2.1 power. The capital cost was reported as Total Overnight Cost (TOC), which includes the bare erected cost of the equipment, plus pre-production costs, inventory capital, and other owner's costs. Other owner's costs were calculated following the methodology in [5], which is calculated as 15% of total plant cost, as a means of capturing the costs for pre-FEED studies, economic development, improvements outside the site boundary, legal and permitting costs, owner's engineering and owner's contingency.
- *Capital cost of PCC Compression.* Likewise, the team consulted [2] for cost data to scale the cost of PCC compression to increased CO_2 flowrate. For the PCC compression equipment, the cost scaled to the ratio of the CO_2 flowrates, raised to the 0.6 power. The team added 15% to the compressor purchased equipment cost to reflect modifications (such as addition of a variable frequency drive) to enable frequent starts and stops of the compression equipment. The team assumed that the Case B31B compressor was not designed for such operation, since this was not stated as part of the design basis in [5], and the B31B had a more traditional annual capacity factor of 0.85 (i.e., reflecting base load operation). The capital cost was reported as TOC, which includes the bare erected cost of the equipment, plus pre-production costs, inventory capital, and other owner's costs. Other owner's costs were calculated following the methodology in [5], which is calculated as 15% of total plant cost, as a means of capturing the costs for pre-FEED studies, economic development, improvements outside the site boundary, legal and permitting costs, owner's engineering and owner's contingency.
- *Fixed O&M of PCC and PCC compression.* The team adjusted the B31B fixed O&M

costs to reflect 97% capture. The increase in capture rate from 90% to 97% should not require additional staff to operate the plant. Maintenance labor, property tax, and insurance were calculated as percentages of the total plant cost, so these values increased due to the increase in capital cost for 97% CO_2 capture. Property Taxes and Insurance (PT&I) was reported separately from the other fixed O&M costs.

- *Variable O&M of PCC and PCC compression.* The team scaled the consumable costs linearly with the amount of CO_2 captured. The maintenance materials costs were calculated as a percentage of the total plant cost; these values increased due to the increase in capital cost for 97% CO_2 capture.

5.2.1. Size Scaling Exponents

DOE provides the following equipment scaling exponents in [14]:

- PCC system:
  - The scaling exponents for the Cansolv removal system installed at an NGCC unit (for a constant CO_2 removal rate) is approximately 0.60 when sized by CO_2 flowrate and/or flue gas flowrate.
  - The Cansolv scaling factor is limited to being applied over a fairly narrow size range (±2.5%).
- PCC compression:
  - The team has quotes for Integrally Geared Compressors from several vendors which support a scaling exponent of 0.60 when sized by compressor duty for a constant suction/discharge pressure.
  - The DOE Quality Guidelines [14] appear to have a typo in scaling exponent for compressor. Table 3-32 shows 0.41 scaling factor for NGCC PCC Compressor, but Table 3-6 shows 0.61 scaling exponent for compressors operating over same range of duty and same suction/discharge pressures. The 0.41 is likely a typo.

The final cost for the PCC unit and the compressors is given in Tables 22 and 23.

Table 22: Cost data for PCC

cost data	unit	value
sizing	tonne/h	250
total capital cost (TOC)	$	887,213,895
normalized capital cost (TOC)	$/(tonne/h)	3,542,734
annual non-PT&I fixed O&M cost	$/year	7,595,858
normalized non-PT&I fixed O&M cost	$/tonne CO_2/h-year	30,331
Property Taxes and Insurance (PT&I) cost	$/year	14,597,566
normalized PT&I cost	$/tonne CO_2/h-year	58,290
annual variable O&M (at 100% CF)	$/year	18,527,935
normalized variable O&M	$/(tonne CO_2)	8.45

Table 23: Cost data for PCC compressor

cost data	unit	value
sizing (mass CO_2)	tonne/h	250
sizing (duty)	MW	19.14
total capital cost (TOC)	$	80,822,010
normalized capital cost (TOC)	$/MW	4,223,023
annual non-PT&I fixed O&M cost	$/year	700,183
normalized non-PT&I fixed O&M cost	$/MW-year	36,585
PT&I cost	$/year	1,329,786
normalized PT&I cost	$/MW-year	69,483
annual variable O&M (at 100% CF)	$/year	1,745,198
normalized variable O&M	$/MWh	10.41

5.3. DAC & DAC Purification and Compression

5.3.1. DAC

The capital cost of the DAC unit was estimated based on another project which will be published separately in the future. The final unit cost is:

- blower/pump cost: \$491.04/(m^3/s). This serves as the unit adsorption/desorption system cost in the main text.
- contactor cost: \$72.72/(kg sorbent). This serves as the unit sorbent cost in the main text.

The fixed O&M cost of the DAC system is assumed to be 5% of its total plant cost plus the salary for two operators (\$110,000 per person per year). Its variable O&M cost is assumed to be caused by the sorbent aging and the unit cost is \$9/tonne CO_2.

5.3.2. DAC Purification and Compression

The team recently developed a bottoms-up design and cost estimate for a liquefaction/distillation plant of very similar size to the one required for this project. The team scaled this in-house cost and performance data as follows:

- *Steam requirement.* The DAC compression and purification system does not require steam.
- *Power requirement.* The DAC compression and purification system power requirement was scaled linearly with the CO_2 flowrate.
- *Cooling water requirement.* The cooling water requirement was scaled linearly with CO_2 flowrate.
- *Capital cost of DAC compression.* The size of the liquefaction/distillation system required for this project is very close to the system the team had designed and costed for others. The team added costs for a second distillation column so that the system could achieve the required turndown of ~25%. The team applied a size scaling exponent of 0.6 to adjust the purchased equipment cost to the flowrate for this project. The capital cost is reported as the Total Overnight Cost (TOC), which includes the bare

erected cost of the equipment, plus pre-production costs, inventory capital, and other owner's costs. Other owner's costs were calculated following the methodology in [5], which is calculated as 15% of total plant cost, as a means of capturing the costs for pre-FEED studies, economic development, improvements outside the site boundary, legal and permitting costs, owner's engineering and owner's contingency.

- *Fixed O&M of DAC compression.* The team calculated fixed O&M costs on the basis that an additional 0.5 operator would be required to operate the DAC compression plant. Maintenance labor, administrative labor, property tax, and insurance were calculated as a percentage of the total plant cost, using the same percentage as Case B31B [5]. PT&I were reported separately from the other fixed O&M costs.
- *Variable O&M of DAC compression.* Consumable costs for the DAC compression consist of molecular sieve sorbent for the dehydration unit, which must be replaced and disposed approximately every 3 years. In addition, maintenance materials costs were calculated as a percentage of the total plant cost.

The final cost for the DAC compressors is given in Tables 24.

Table 24: Cost data for DAC Compressor

cost data	unit	value
sizing (mass CO_2)	tonne/h	140
sizing (duty)	MW	19.4
total capital cost (TOC)	$	87,596,398
normalized capital cost	$/MW	4,520,150
annual non-PT&I fixed O&M	$/year	958,616
normalized non-PT&I fixed O&M Cost	$/MW-year	49,467
PT&I cost	$/year	1,441,247
normalized PT&I cost	$/MW-year	74,371
annual variable O&M (at 100% CF)	$/year	869,983
normalized variable O&M	$/MWh	5.12

6. Start-Up Modeling

6.1. NGCC Start-Up

To support various aspects of the project, a start-up sequence (Figure 15) for the NGCC was derived from literature sources [7]. This start-up sequence did not represent an actual operating NGCC plant but is a compilation of several technical papers. This start-up sequence was then expanded to determine how the PCC and DAC system would be integrated into the start-up sequence of a 2 $\times$ 1 NGCC.

After the gas turbine is ignited and accelerated to synchronous speed, it would hold at that load (Full Speed No Load, FSNL) for a period of time to allow the tubing and the water in the HRSG to heat. As the temperature of the HRSG increases, it would begin generating steam at a low pressure, temperature, and flowrate. This steam would be used for heating the steam piping, evacuating the steam turbine condenser and to begin commissioning the steam turbine sealing system. In a conventional NGCC start-up, the excess steam generated but not utilized by the NGCC during the start-up flows to the steam turbine condenser to be cooled back to liquid water and then pumped back to the HRSG. During this early phase of the start-up, the excess steam that would normally flow to the steam turbine condenser could be used to begin preheating the PCC system and the DAC by diverting the steam into the LP steam system as shown in Figure 21. The combined steam flow entering the LP steam system would be superheated, so it would first flow through DAC Steam Generation System (HX-5 in Figure 13) to be desuperheated before being used in the PCC Regenerator Reboiler to begin heating the solvent for the PCC system. Desuperheating the steam in HX-5 would raise saturated steam in the DAC Steam Generation System for use by the DAC. Since the PCC would not be ready for operation during this phase of the start-up, the exhaust gas from the gas turbine would bypass the PCC system and exhaust to the atmosphere. Once the HRSG reached the desired temperature while the gas turbine was operating at FSNL, the load of the gas turbine would be increased to a minimum load (shown as 20% in Figure 20) to increase the production of steam in the HRSG to increase the pressure, temperature, and flowrate of the steam produced by the HRSG in preparation of supplying steam to the steam turbine.

Once the HRSG was at an adequate load, HP steam would be supplied to the steam turbine. Initially the flow would be low as the steam turbine is slowly heated and its rotational speed is increased to synchronous speed. The excess steam that is not flowing to the steam turbine would continue to flow to the LP steam system or the steam turbine condenser. Once the steam turbine is operating at its normal operating speed, the gas turbine load would increase. The additional heat from the gas turbine would raise more steam in the HRSG, which would supply more steam to the steam turbine, increasing the electrical output from both the first gas turbine as well as the steam turbine. The steam exhausting from the IP turbine flows into the LP steam distribution system shown in Figure 13. As the steam flowrate exhausting from IP Turbine increases, the priority for the steam would be for the PCC system so that it could begin accepting the exhaust gas from the first gas turbine and begin removing 97% of the CO_2 before exhausting the gas to the atmosphere. Since the steam exhausting from the IP Turbine would be superheated, it would flow through the DAC steam generation system for desuperheating before flowing to the PCC system. Due to this desuperheating in HX-5, as the steam flow to the PCC system increases during start-up, the DAC steam flowrate would also increase. The remaining LP steam that is not utilized in the PCC system would flow to the LP Turbine to begin heating this steam turbine and generating power as shown in Figure 22.

At the appropriate time in the start-up sequence, the second gas turbine and HRSG would begin operation. Like the first unit, the gas turbine would initially operate at FSNL and as the HSRG begins heating and generating steam the gas turbine load would increase to a minimum load (shown as 20% in Figure 20). Since the PCC would already be in operation, the exhaust gas from the second gas turbine would flow into the PCC system as soon as the flowrates were stable so that 97% of the CO_2 could be removed from the gas before it is exhausted to the atmosphere. In this early part of start-up, the steam generated by the second HRSG is at too low of a pressure, temperature, and flowrate to be integrated with the flow of steam going to the steam turbine. However, it is likely that the steam conditions would be adequate for the LP steam system, allowing it to be utilized in the LP turbine to generate power or into the DAC system to remove CO_2 from the atmosphere as shown in Figure 23.

Once the second gas turbine and HRSG are at the correct temperature and load, the steam from the second gas turbine/HRSG would be integrated with the steam from the first gas turbine/HRSG and both units would supply steam to the steam turbine, fully integrating the steam cycles as shown in Figure 24. The overall electrical load produced by the NGCC would meet the load required by the utility's dispatch control and the split of LP steam to the LP Turbine or to the DAC would be based on the current prices of electrical power or CO_2 removal, allowing the unit to maximize its revenue.

At periods of high CO_2 removal prices, the unit would operate in a "max DAC" mode as shown in Figure 15 and Figure 25. The LP steam flow that would be supplied to the LP Turbine would be supplied to the LP Steam Condenser (HX-7 in Figure 15), which would significantly increase the amount of steam generated by the DAC steam generation system. This additional steam flow would be utilized to remove CO_2 from the atmosphere using the DAC. Figure 25 shows that the LP Turbine would be turned off, but a minimum steam flow would flow through the LP Turbine on a continuous basis so that it would be ready for operation if the relative price of electricity vs. CO_2 removal changed, and the unit needed to produce more power using the LP Turbine.

6.2. PCC Start-Up

At a high-level, the start-up of the PCC involves the following major steps and associated requirements:

- Solvent circulation to wet column internals, etc.; electricity required
- Heating of steam piping to PCC and regenerator reboiler; power plant steam required
- Heating of the solvent inventory to reboiler operating temperature to allow continuous solvent regeneration; power plant steam required
- Stabilization of the PCC after flue gas introduction to the absorber

The PCC unit becomes a bottleneck for CO_2 abatement relative to the power plant start-up sequence during the heating steps outlined above–at that point, the power plant is producing flue gas that could be treated by the PCC, but the solvent cannot be regenerated, resulting in the CO_2 being emitted unabated. The availability of steam and the steam conditions from the power plant, the solvent inventory, and the thermal mass of the piping and reboiler are factors in determining the time to reach the steady-state solvent regeneration temperature.

Research on flexible operation of PCC units has included concepts such as lean solvent storage to decouple the regeneration and absorption system (and effectively decouple CO_2 capture from the power plant for limited periods of time). Flexible PCC concepts such as lean solvent storage require additional capital investment and require a careful cost-benefit analysis to determine the value of the concepts. This would represent a potential optimization after understanding the dispatch behavior of the NGCC with PCC (and direct air capture). For this initial high-level evaluation of start-up, no additional capital investment for flexible operation was considered. Instead, the focus was on quantifying the unabated emissions from the power plant during start-up as the primary "cost" of PCC start-up.

Table 33 shows the start-up sequence. The status of the PCC unit (capture or no capture) is shown for each step in the start-up sequence. During the first 2.22 hours of the start-up of Gas Turbine #1, the PCC is not capturing CO_2 from the combusted natural gas. Steam is available early during this period and is used in some specific places in the power plant (e.g., steam turbine sealing system), but most of the steam is sent to the power plant condenser. For the case of plant start-up with a PCC unit, some portion of this steam will be diverted to heating the steam piping, reboiler, and solvent inventory for the capture system. This steam heating of the PCC system will continue through the synchronization and ramp to 20% load (i.e., through 2.22 hours in the start-up sequence). For the purposes of this project, no CO_2 capture occurs in this period and CO_2 is emitted unabated–the team views this as a conservative assumption for heating the CO_2 capture regeneration system and stabilizing the system for CO_2 capture based on a review of literature and expectations for the amount of steam available and heating requirements for the PCC. A more detailed evaluation of the PCC start-up could likely optimize the heat-up and capture initiation timing. When Gas Turbine #2 starts up, the PCC regeneration system is already heated and operating and steam will already be available such that CO_2 capture can occur during the very first start-up step of Gas Turbine #2.

6.3. DAC Start-Up

As it is challenging to accurately estimate the amount of LP steam during the start-up, it is assumed that there is no extra LP steam available for the DAC unit and the unit stays closed during the procedure. This assumption is viewed as a conservative estimation.

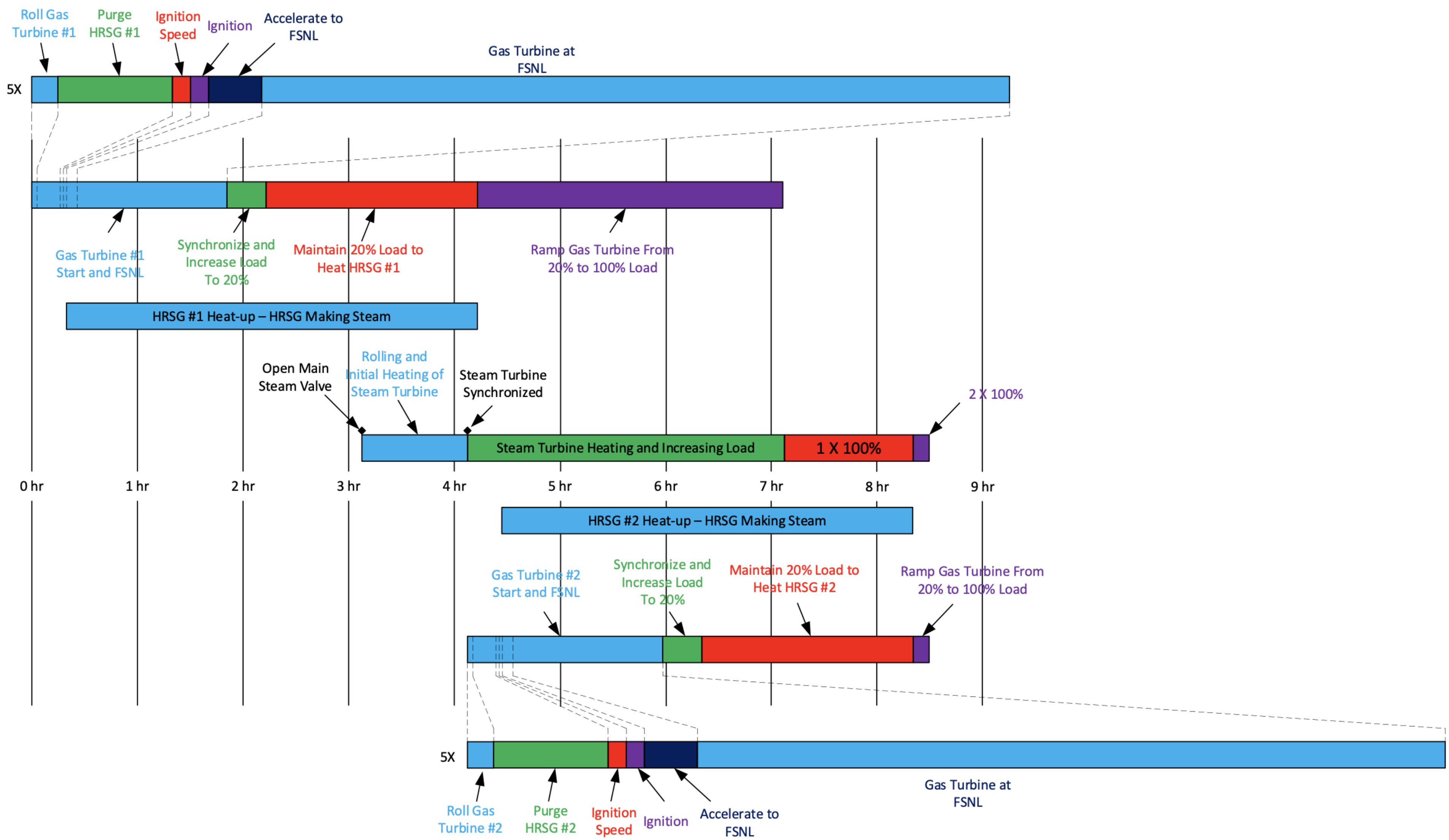

Figure 15: 2 × 1 NGCC Start-Up Derived from Literature Sources

Table 25: PCC status during start-up of gas turbines #1 and #2

Gas Turbine #1					
hour	GT# 1 status	GT CO_2 emission lb/h	fuel flow lb/h	PCC status	Comments
0–1.85	turbine roll-off to FSNL	70,685	25,704	heating, no capture	Natural gas flow is 25% of full load flow.
1.85–2.22	synchronize, ramp to 20% load	113,097	41,126	heating/stabilizing, no capture	
2.22–4.22	hold at 20% for HRSG heating	113,097	41,126	97% CO_2 capture	
4.22–7.11	ramp to 100% load	see comments	see comments	97% CO_2 capture	Natural gas flow will vary linearly from 20% to 100% load case during this period. CO_2 emissions will track.
Gas Turbine #2					
hour	GT# 2 status	GT CO_2 emission lb/h	fuel flow lb/h	PCC status	Comments
4.12–5.97	turbine roll-off to FSNL	70,685	25,704	97% CO_2 capture	Natural gas flow is 25% of full load flow.
5.97–6.34	synchronize, ramp to 20% load	113,097	41,126	97% CO_2 capture	
6.34–8.34	hold at 20% for HRSG heating	113,097	41,126	97% CO_2 capture	
8.34–end	ramp to 100% load	see comments	see comments	97% CO_2 capture	Natural gas flow will vary linearly from 20% to 100% load case during this period. CO_2 emissions will track.

7. NPV Estimation Steps

This section explains the NPV estimation steps reflected in Table 6 of the main text and their relation to the base and retrofit optimization models.

7.1. Cash Flow Table

Total Depreciable Capital Investment (C_{TDC}). This term reflects the TOC for the retrofit spent in each year. Since the construction period is two years and the TOC distribution is 30%/70%, the first two years of the table have $\mathrm{C}_{\mathrm{TDC}}$ values corresponding to 30%/70% of the total TOC. The total TOC includes the TOC of the DAC unit (to be determined by the optimization model) and other parts (pre-determined).

Working Capital (C_{WC}). This term represents the operating costs required for the early plant operations and is assumed to be 0 as guided by [13].

Depreciation (D). This term reflects the reduction in value of the asset and can be treated as a cost of production to reduce income tax liability. As the depreciation method is 150% declining balance for 20 years, the annual depreciation is

$$\mathrm{D}_t = d \cdot \mathrm{B} \cdot (1-d)^{t-1}, \tag{13}$$

where $d = 150\%/20 = 7.5\%$, B is the original cost of the asset, and t is the year since the completion of the construction. As the NGCC capital cost is not counted in the capital investment, its depreciation is not considered either.

Cost of Sales Excluding Depreciation ($C_{Excl.\ Dep.}$). This term is derived from the solution of the optimization model and is composed of the annual fixed and variable O&M cost of the plant, the start-up cost, the fuel cost, and the CO_2 transportation cost. It is assumed identical for each year of operation.

Sales (S). This term is derived from the solutions of both optimization models. It is the sum of the annual electricity profit and CO_2 credit from the retrofit model minus the base NGCC profit (electricity profit minus costs and CO_2 penalty). It is identical for each year of operation.

Net Earnings. This term reflects the annual net profit after tax,

$$(\text{net earnings})_t = (\mathrm{S} - \mathrm{C}_{\text{Excl. Dep.}} - \mathrm{D}_t) \cdot (1 - r^{\text{tax}}), \tag{14}$$

where r^{tax} is the income tax rate.

Cash Flow. This term represents cash receipts minus cash payments over the year and is equal to the sum of net earnings and the depreciation:

$$(\text{cash flow})_t = (\text{net earnings})_t + \mathrm{D}_t. \tag{15}$$

Present Value (PV). This term is the value of future money at the current moment considering compound interests. Assuming the interest rate is i,

$$(\text{PV})_t = \frac{(\text{cash flow})_t}{(1+i)^{t-1}}, \tag{16}$$

where t is the year since the beginning of construction.

Cumulative PV. This is the cumulative sum of PV since the beginning of construction:

$$(\text{cum. PV})_t = \sum_{i=1}^{t} (\text{PV})_i. \tag{17}$$

The cumulative PV in the last (22^{nd}) year of the operation period is the final NPV.

7.2. Correspondence with Optimization Models

From the calculations above, it can be shown that the final NPV is a linear function of five variables that are determined by the optimization models: the capital cost of the DAC, the annual operating costs of the base case and retrofit systems, and the annual profits of the base case and retrofit systems. The coefficients of these variables are derived below and used in the objectives of the optimization models.

Capital Cost of DAC. This value is a part of the total capital cost and affects three columns (C_{TDC}, D, and cash flow). Moreover, the variable $x\text{Cost}^{\text{DAC,TPC}}$ needs to be transformed from TPC to TOC to be counted in the capital cost. Taking all of these impacts into consideration, the overall coefficient is

$$a\text{Cost}^{\text{cap}} = a\text{Ratio}^{\text{TOC, TPC}} \cdot \left[0.3 + \frac{0.7}{1+i} - r^{\text{tax}} \cdot \sum_{t=0}^{19} d \cdot (1-d)^t \cdot \frac{1}{(1+i)^{t+2}} \right], \tag{18}$$

where $a\text{Ratio}^{\text{TOC, TPC}}$ is the ratio between TOC and TPC. The first two terms in the brackets correspond to the impact on C_{TDC}, while the third corresponds to the impact on D and cash flow. Since depreciation is deducted from net earnings before tax and added back in the cash flow, its impact on cash flow is its original value times the tax rate r^{tax}. Summing up the ratio for all 20 years and plugging in (13) leads to the third term.

Annual Operating Cost and Profit. The annual operating cost and profit determine $\text{C}_{\text{Excl. Dep.}}$ and S, respectively, and impact the NPV in a similar manner. The coefficient needs to consider the cumulative time value:

$$a\text{Cost}^{\text{op}} = (1 - r^{\text{tax}}) \cdot \sum_{t=0}^{19} \frac{1}{(1+i)^{t+2}}, \tag{19}$$

This coefficient is also used in the base NGCC model.

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