

Supplementary Information for:

**Decarbonization Approaches for Ethylene Production:
Comparative Techno-Economic and Life-Cycle Analysis**

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22 pages, including 10 tables and 16 figures

Figure S1. Process configurations of Baseline case with stream numbers & information shown in Table S1.

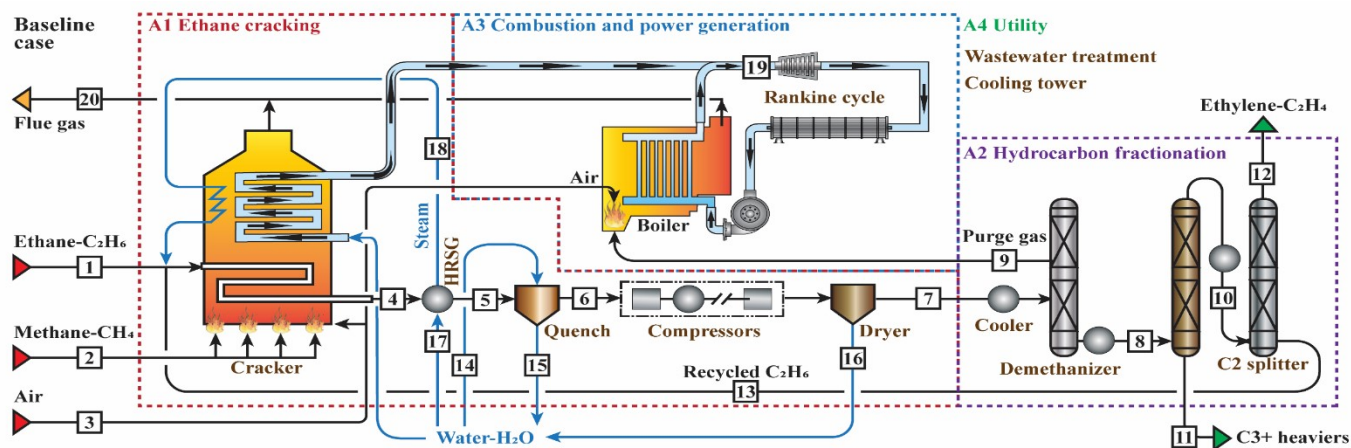


Figure S2. Screen copy of our Aspen Plus model for Baseline case: Main Flowsheet.

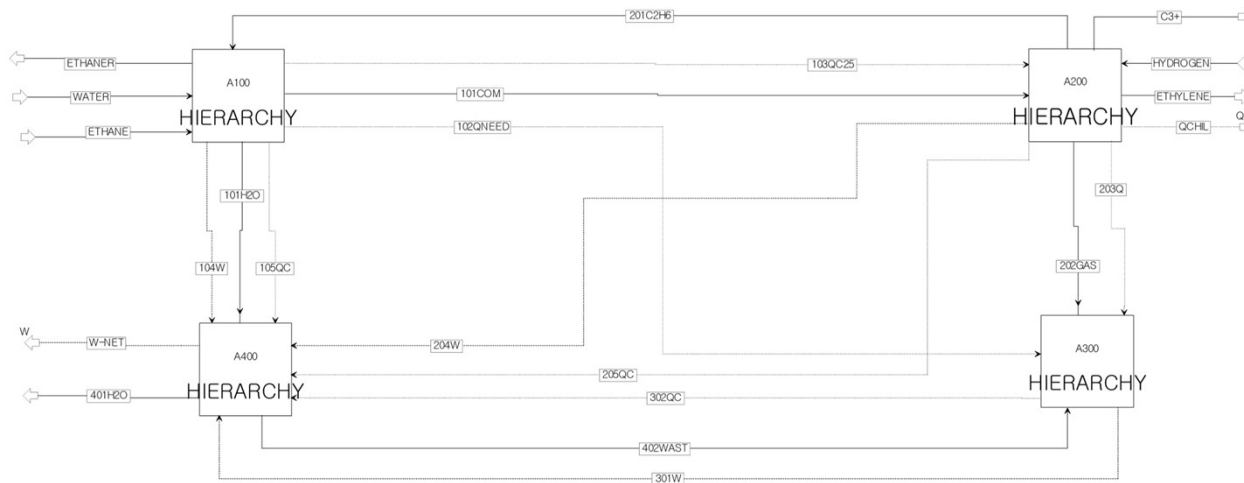
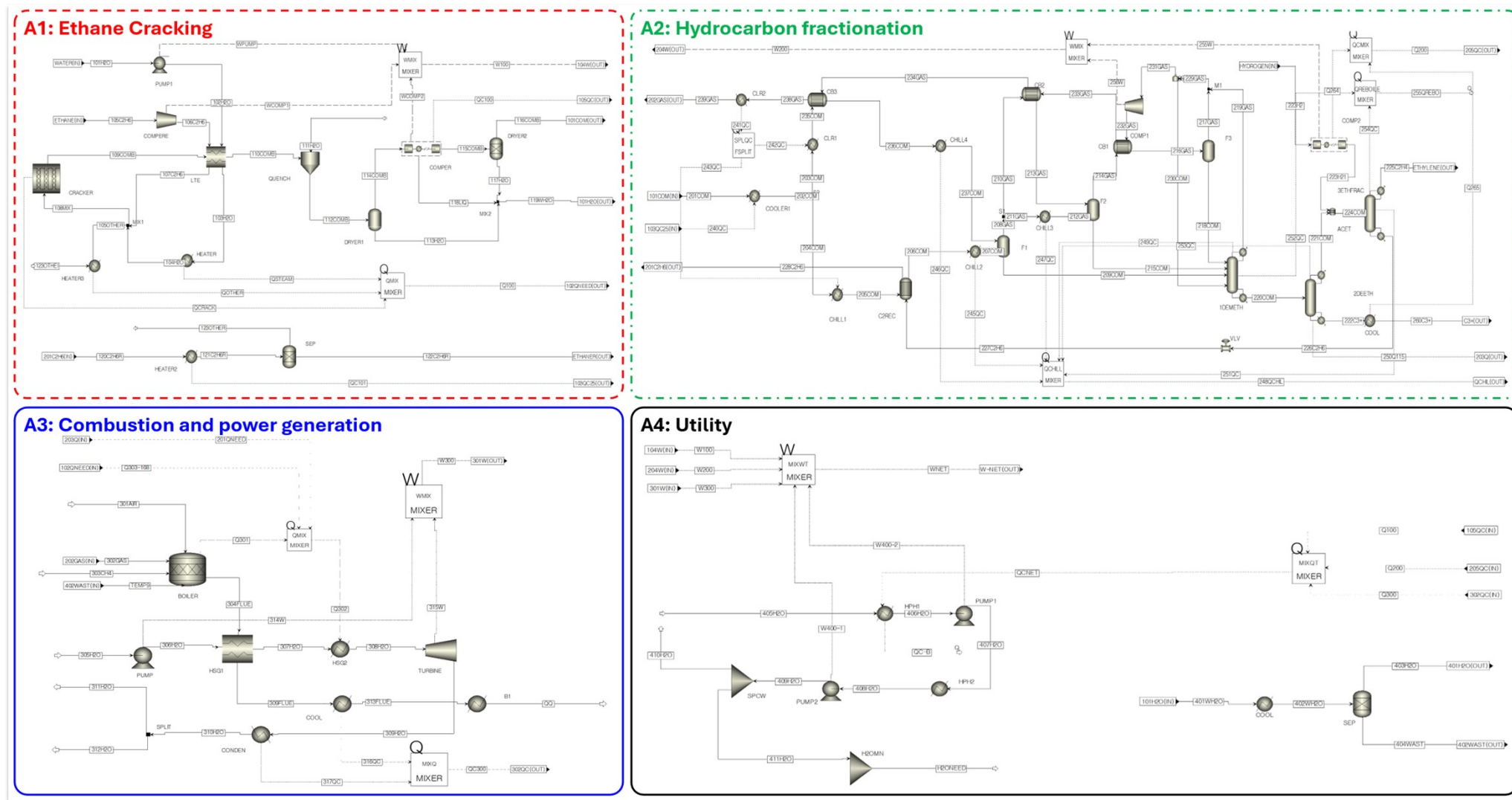


Figure S3. Screen copy of our Aspen Plus model for Baseline case: A1–A4 Flowsheet.



The diagram illustrates an integrated process for ethane cracking and power generation, divided into four main sections:

- A1 Ethane cracking:** Ethane (C_2H_6) (stream 1) and Air (stream 2) enter a Cracker. Flue gas (stream 19) is also shown. The Cracker produces a gas stream (stream 3) and a liquid stream (stream 13).
- A2 Hydrocarbon fractionation:** The gas stream (stream 3) is cooled in a HRSG (Heat Recovery Steam Generator) (stream 4) and then in a Quench (stream 5). The liquid stream (stream 13) is also cooled in the Quench (stream 14). The Quench output (stream 5) is compressed (stream 6) and dried (stream 15). The dried gas (stream 15) is cooled (stream 7) and then enters a Demethanizer. The Demethanizer separates Ethylene (C_2H_4) (stream 11) from a C2 splitter. The C2 splitter separates Ethylene (C_2H_4) (stream 11) from C3+ heavies (stream 10). The C2 splitter also separates a Purge gas (stream 8) from a Cooler (stream 9).
- A3 Combustion and power generation:** The gas stream (stream 3) is burned in a Boiler. The Boiler output (stream 17) is used in a Rankine cycle. The Rankine cycle also receives Air (stream 18) and produces Steam (stream 16). The Rankine cycle output (stream 18) is used in a Cooling tower. The Cooling tower output (stream 19) is used in the Cracker.
- A4 Utility:** The Cooling tower output (stream 19) is used in the Cracker.

Key components and streams include:

- Cracker:** The main reactor for ethane cracking.
- HRSG (Heat Recovery Steam Generator):** Recovers heat from the cracking process to generate steam.
- Quench:** Cools the cracking gas and liquid streams.
- Compressors:** Compress the gas stream for further processing.
- Dryer:** Removes moisture from the gas stream.
- Demethanizer:** Separates ethylene from the gas stream.
- C2 splitter:** Separates ethylene from C3+ heavies.
- Boiler:** Burns the cracking gas to generate steam.
- Rankine cycle:** Converts steam into electricity.
- Cooling tower:** Cools the Rankine cycle output.

The figure contains four detailed process flow diagrams:

- A1: Ethane Cracking**: Shows the cracking of ethane (C_2H_6) into ethylene (C_2H_4). The process includes feed streams (Water, Ethane), pumps, heaters, mixers, a quench section, dryers, compressors, and various heat exchangers. Key components include a steam boiler, a gas compressor, and a condenser.
- A2: Hydrocarbon fractionation**: Illustrates the separation of hydrocarbons into different fractions. It features multiple distillation columns (F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, F18, F19, F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F30, F31, F32, F33, F34, F35, F36, F37, F38, F39, F40, F41, F42, F43, F44, F45, F46, F47, F48, F49, F50, F51, F52, F53, F54, F55, F56, F57, F58, F59, F60, F61, F62, F63, F64, F65, F66, F67, F68, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79, F80, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F93, F94, F95, F96, F97, F98, F99, F100, F101, F102, F103, F104, F105, F106, F107, F108, F109, F110, F111, F112, F113, F114, F115, F116, F117, F118, F119, F120, F121, F122, F123, F124, F125, F126, F127, F128, F129, F130, F131, F132, F133, F134, F135, F136, F137, F138, F139, F140, F141, F142, F143, F144, F145, F146, F147, F148, F149, F150, F151, F152, F153, F154, F155, F156, F157, F158, F159, F160, F161, F162, F163, F164, F165, F166, F167, F168, F169, F170, F171, F172, F173, F174, F175, F176, F177, F178, F179, F180, F181, F182, F183, F184, F185, F186, F187, F188, F189, F190, F191, F192, F193, F194, F195, F196, F197, F198, F199, F200, F201, F202, F203, F204, F205, F206, F207, F208, F209, F210, F211, F212, F213, F214, F215, F216, F217, F218, F219, F220, F221, F222, F223, F224, F225, F226, F227, F228, F229, F230, F231, F232, F233, F234, F235, F236, F237, F238, F239, F240, F241, F242, F243, F244, F245, F246, F247, F248, F249, F250, F251, F252, F253, F254, F255, F256, F257, F258, F259, F260, F261, F262, F263, F264, F265, F266, F267, F268, F269, F270, F271, F272, F273, F274, F275, F276, F277, F278, F279, F280, F281, F282, F283, F284, F285, F286, F287, F288, F289, F290, F291, F292, F293, F294, F295, F296, F297, F298, F299, F300, F301, F302, F303, F304, F305, F306, F307, F308, F309, F310, F311, F312, F313, F314, F315, F316, F317, F318, F319, F320, F321, F322, F323, F324, F325, F326, F327, F328, F329, F330, F331, F332, F333, F334, F335, F336, F337, F338, F339, F340, F341, F342, F343, F344, F345, F346, F347, F348, F349, F350, F351, F352, F353, F354, F355, F356, F357, F358, F359, F360, F361, F362, F363, F364, F365, F366, F367, F368, F369, F370, F371, F372, F373, F374, F375, F376, F377, F378, F379, F380, F381, F382, F383, F384, F385, F386, F387, F388, F389, F390, F391, F392, F393, F394, F395, F396, F397, F398, F399, F400, F401, F402, F403, F404, F405, F406, F407, F408, F409, F410, F411, F412, F413, F414, F415, F416, F417, F418, F419, F420, F421, F422, F423, F424, F425, F426, F427, F428, F429, F430, F431, F432, F433, F434, F435, F436, F437, F438, F439, F440, F441, F442, F443, F444, F445, F446, F447, F448, F449, F450, F451, F452, F453, F454, F455, F456, F457, F458, F459, F460, F461, F462, F463, F464, F465, F466, F467, F468, F469, F470, F471, F472, F473, F474, F475, F476, F477, F478, F479, F480, F481, F482, F483, F484, F485, F486, F487, F488, F489, F490, F491, F492, F493, F494, F495, F496, F497, F498, F499, F500, F501, F502, F503, F504, F505, F506, F507, F508, F509, F510, F511, F512, F513, F514, F515, F516, F517, F518, F519, F520, F521, F522, F523, F524, F525, F526, F527, F528, F529, F530, F531, F532, F533, F534, F535, F536, F537, F538, F539, F540, F541, F542, F543, F544, F545, F546, F547, F548, F549, F550, F551, F552, F553, F554, F555, F556, F557, F558, F559, F560, F561, F562, F563, F564, F565, F566, F567, F568, F569, F570, F571, F572, F573, F574, F575, F576, F577, F578, F579, F580, F581, F582, F583, F584, F585, F586, F587, F588, F589, F590, F591, F592, F593, F594, F595, F596, F597, F598, F599, F600, F601, F602, F603, F604, F605, F606, F607, F608, F609, F610, F611, F612, F613, F614, F615, F616, F617, F618, F619, F620, F621, F622, F623, F624, F625, F626, F627, F628, F629, F630, F631, F632, F633, F634, F635, F636, F637, F638, F639, F640, F641, F642, F643, F644, F645, F646, F647, F648, F649, F650, F651, F652, F653, F654, F655, F656, F657, F658, F659, F660, F661, F662, F663, F664, F665, F666, F667, F668, F669, F670, F671, F672, F673, F674, F675, F676, F677, F678, F679, F680, F681, F682, F683, F684, F685, F686, F687, F688, F689, F690, F691, F692, F693, F694, F695, F696, F697, F698, F699, F700, F701, F702, F703, F704, F705, F706, F707, F708, F709, F710, F711, F712, F713, F714, F715, F716, F717, F718, F719, F720, F721, F722, F723, F724, F725, F726, F727, F728, F729, F730, F731, F732, F733, F734, F735, F736, F737, F738, F739, F740, F741, F742, F743, F744, F745, F746, F747, F748, F749, F750, F751, F752, F753, F754, F755, F756, F757, F758, F759, F760, F761, F762, F763, F764, F765, F766, F767, F768, F769, F770, F771, F772, F773, F774, F775, F776, F777, F778, F779, F780, F781, F782, F783, F784, F785, F786, F787, F788, F789, F790, F791, F792, F793, F794, F795, F796, F797, F798, F799, F800, F801, F802, F803, F

Figure S7. Process configurations of Electrical heating case with stream numbers & information shown in Table S3.

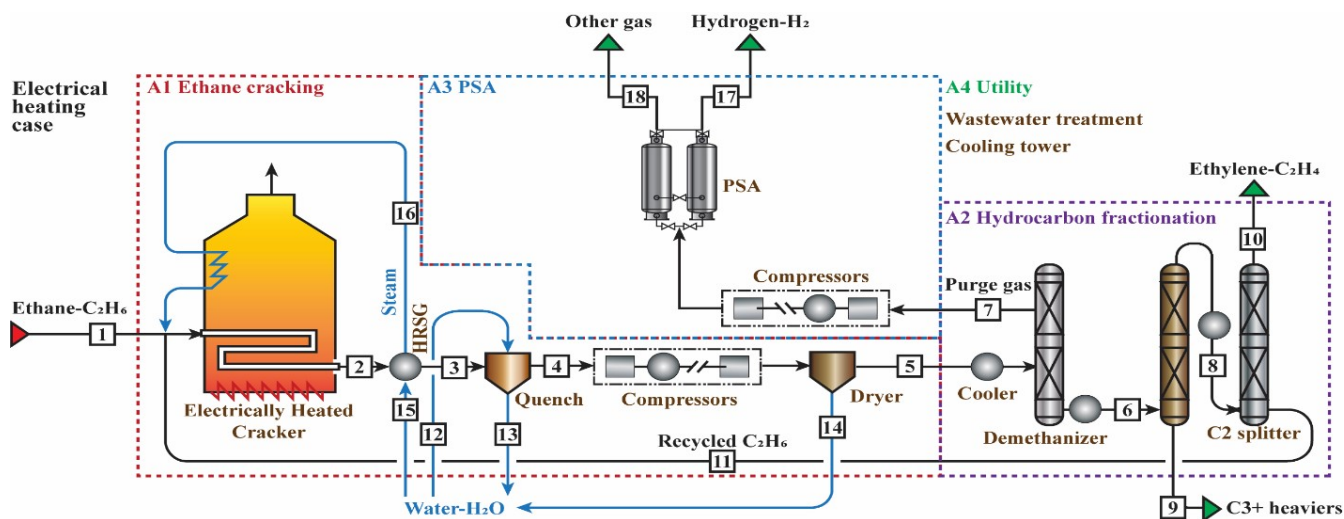


Figure S8. Screen copy of our Aspen Plus model for Electrical heating case: Main Flowsheet.

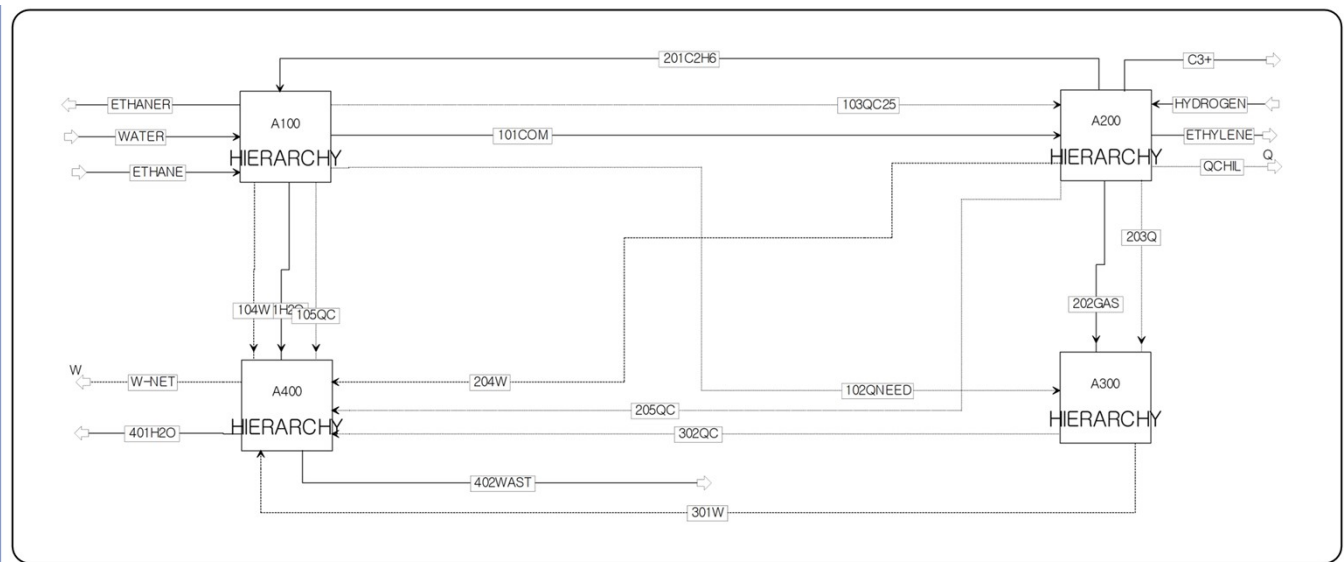


Figure S9. Screen copy of our Aspen Plus model for Electrical heating case: A1–A4 Flowsheet.

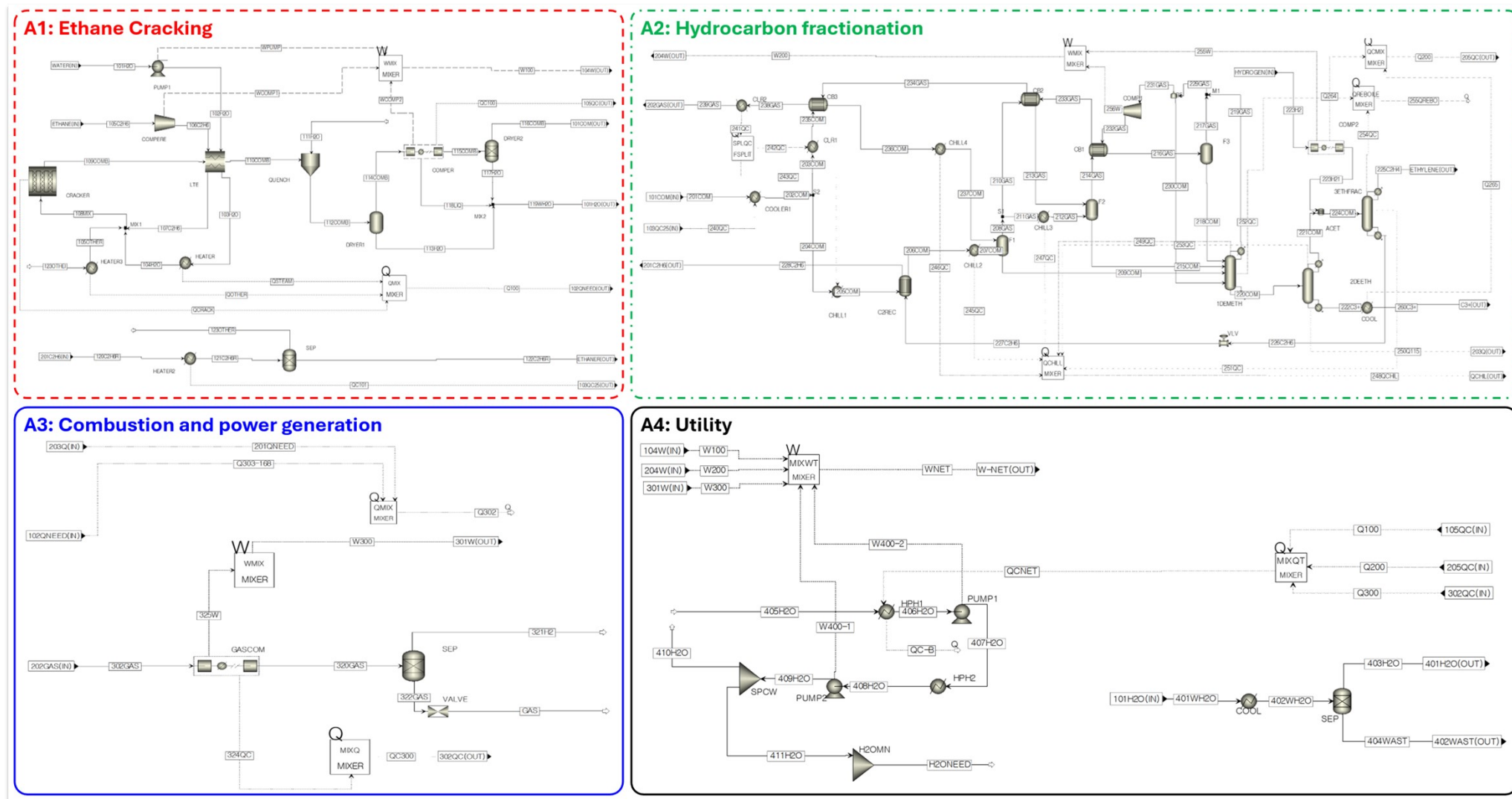


Figure S10. Process configurations of CCS H₂ combustion case with stream numbers & information shown in Table S4.

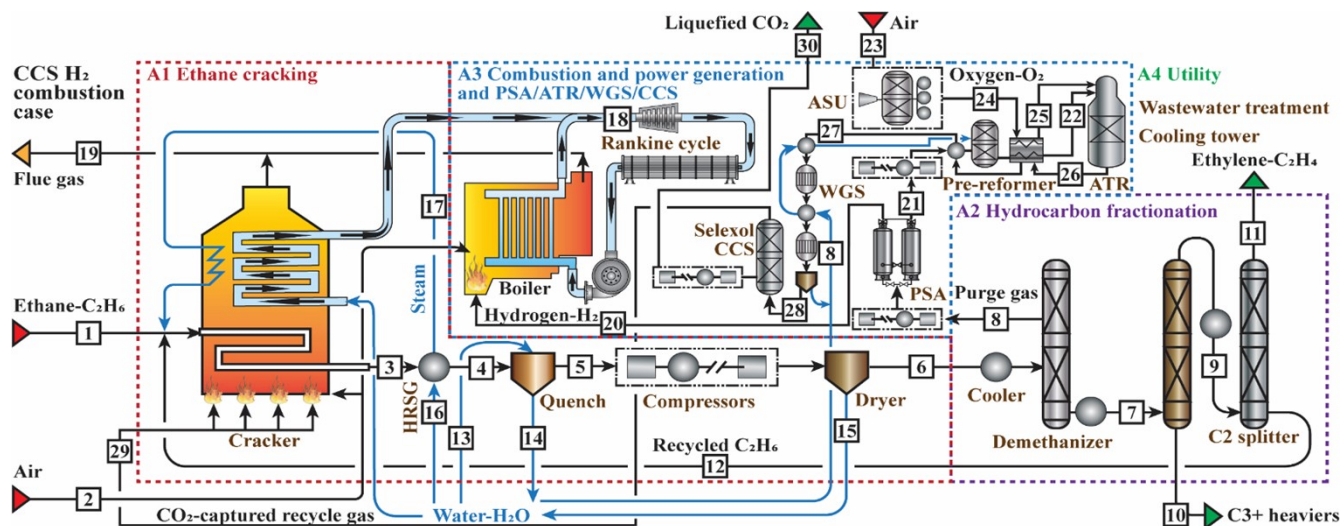


Figure S11. Screen copy of our Aspen Plus model for CCS H₂ combustion case: Main Flowsheet.

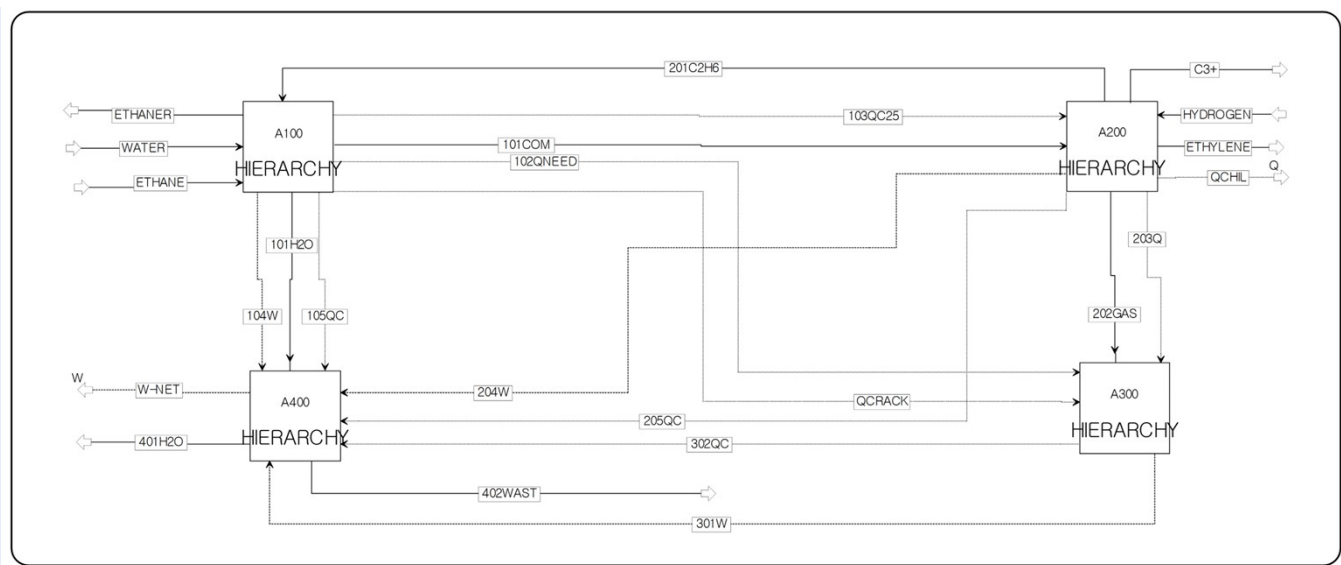


Figure S12. Screen copy of our Aspen Plus model for CCS H₂ combustion case: A1–A4 Flowsheet.

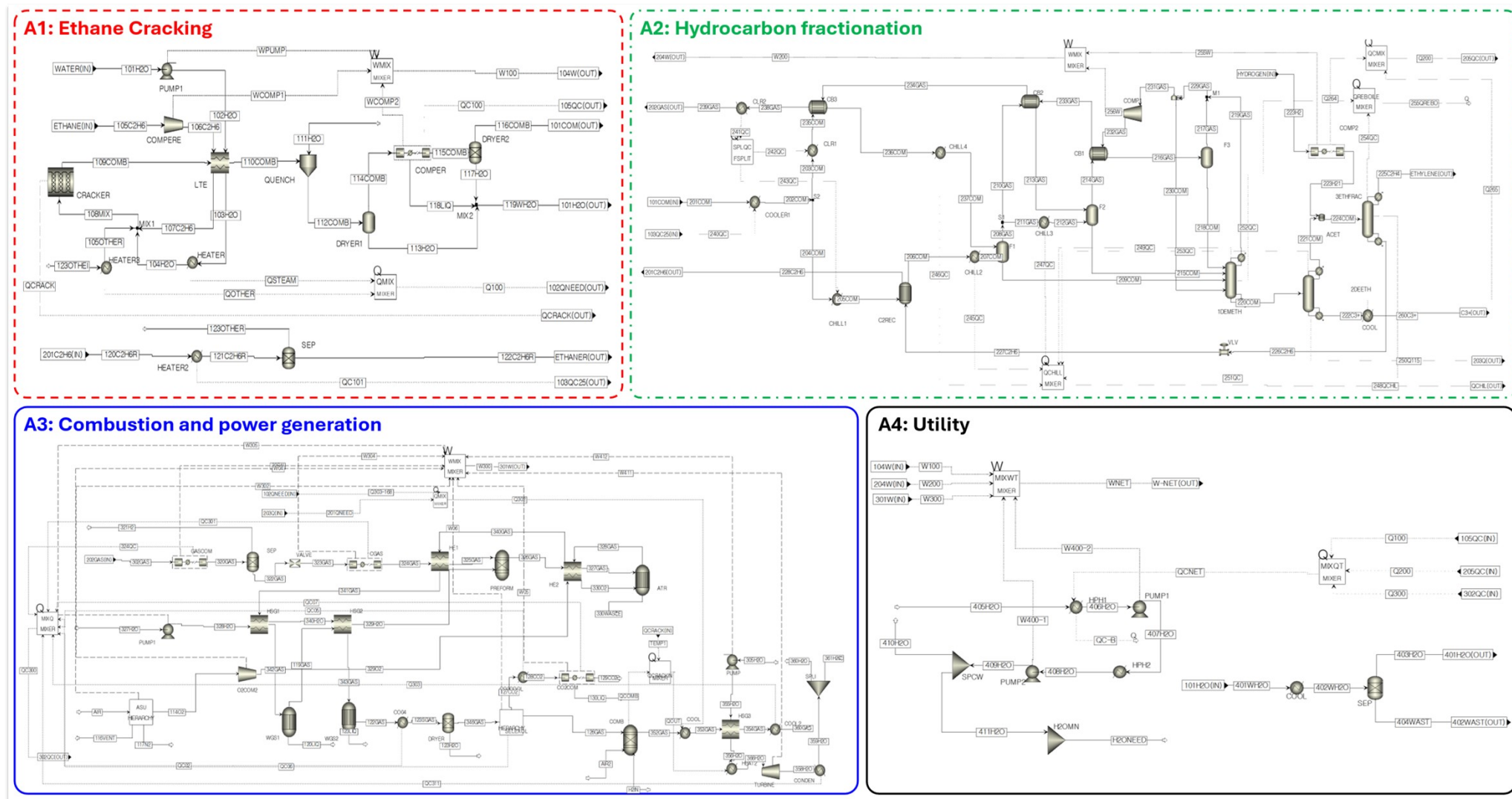


Figure S13. Effects of allocation methods on WTG GHG emissions (Assumption: using grid electricity, substitutes NG-SMR based gray hydrogen in the Electrical heating case, lower heating value (LHV) basis if energy allocation)

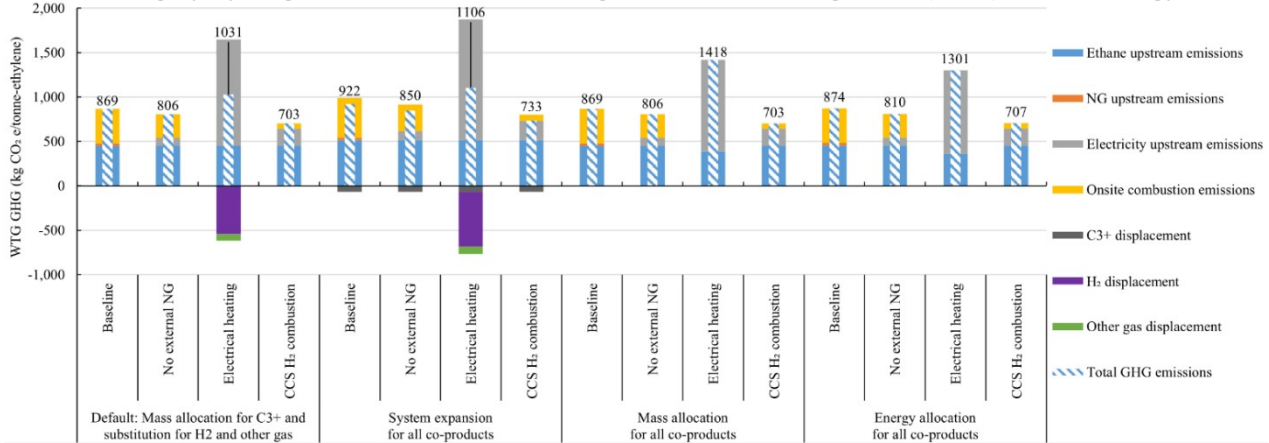


Figure S14. Assumption: renewable electricity, substitute NG-SMR based gray hydrogen

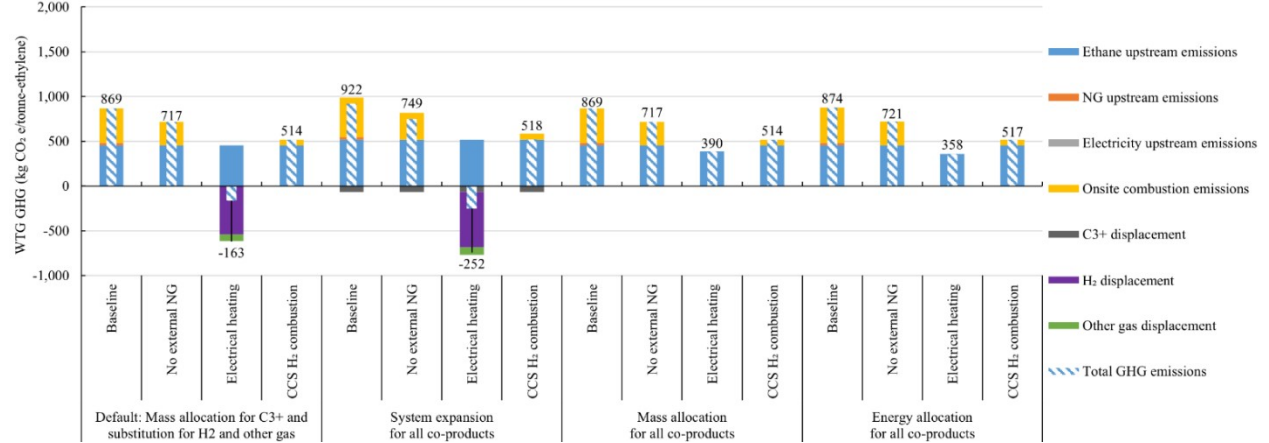


Figure S15. Assumption: renewable electricity, substitute NG-ATR+CCS based blue hydrogen

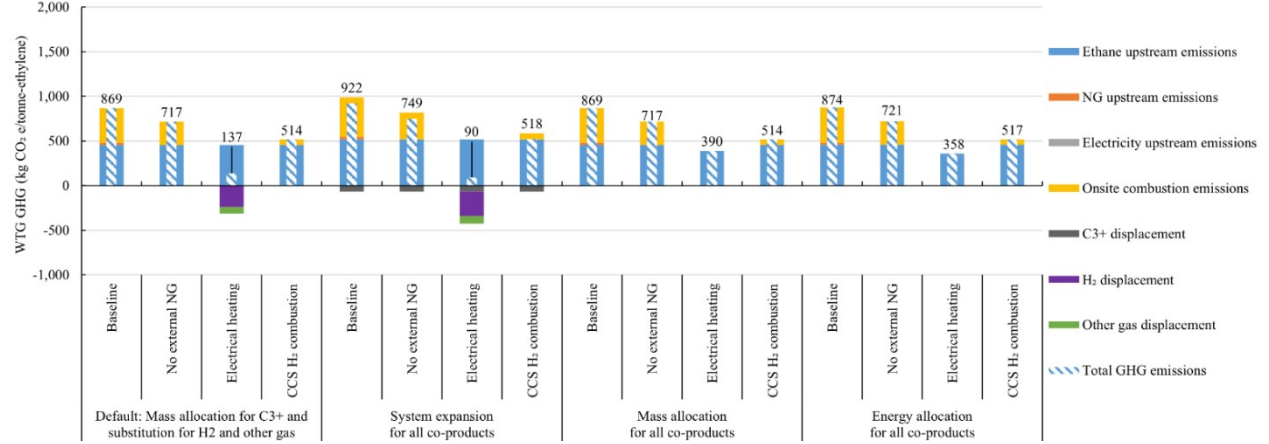


Figure S16. Assumption: renewable electricity, substitute green hydrogen

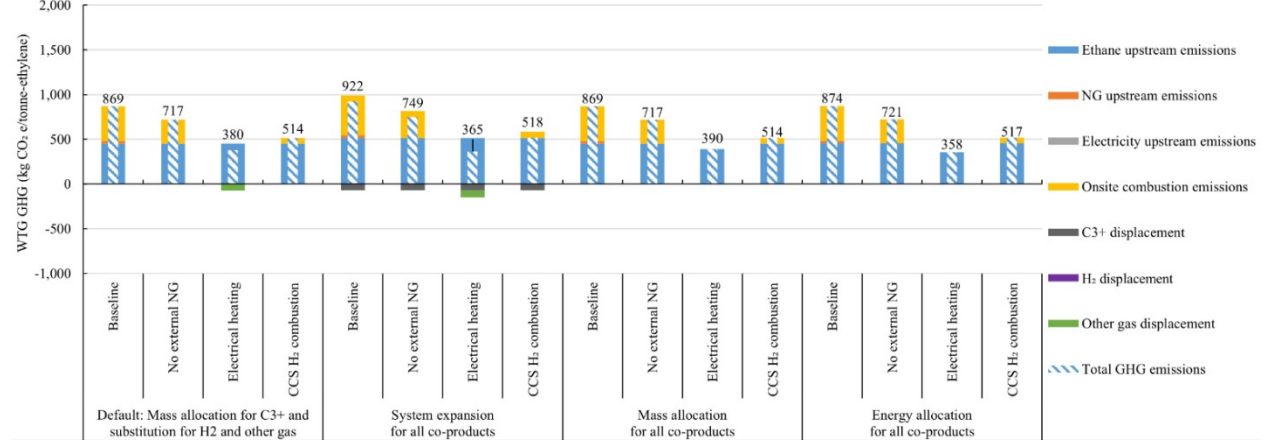


Table S1. Detailed stream information according to the stream number shown in Figure S1 for Baseline case.

Name	Unit	1	2	3	4	5	6	7	8	9	10
Temperature	°C	25.0	25.0	25.0	850.0	200.0	30.0	43.0	3.0	13.0	-14.0
Pressure	Bar	1.0	1.0	1.0	2.2	2.2	2.1	38.0	34.5	4.5	23.4
Mass flow	kg/hr	220,979	5,920	676,995	295,168	295,168	225,138	221,498	200,391	21,107	184,653
Molar flow	kmol/hr	7,349	369	23,466	15,865	15,865	11,978	11,776	6,686	5,091	6,409
C2H6	mol %	100.00%	0.00%	0.00%	14.65%	14.65%	19.41%	19.74%	34.75%	0.03%	36.25%
C2H4	mol %	0.00%	0.00%	0.00%	25.90%	25.90%	34.30%	34.88%	60.96%	0.64%	63.59%
H2	mol %	0.00%	0.00%	0.00%	27.40%	27.40%	36.29%	36.91%	0.00%	85.39%	0.00%
CH4	mol %	0.00%	100.00%	0.00%	4.48%	4.48%	5.93%	6.03%	0.00%	13.94%	0.01%
C2H2	mol %	0.00%	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.04%
C3H6	mol %	0.00%	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.01%
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H8	mol %	0.00%	0.00%	0.00%	1.70%	1.70%	2.25%	2.29%	4.04%	0.00%	0.10%
C4H10	mol %	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
C6H6	mol %	0.00%	0.00%	0.00%	0.07%	0.07%	0.09%	0.09%	0.16%	0.00%	0.00%
H2O	mol %	0.00%	0.00%	0.00%	25.77%	25.77%	1.69%	0.00%	0.00%	0.00%	0.00%
O2	mol %	0.00%	0.00%	21.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N2	mol %	0.00%	0.00%	79.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Name	Unit	11	12	13	14	15	16	17	18	19	20
Temperature	°C	43.0	-35.9	25.0	15.0	30.0	43.2	25.0	263.4	25.0	25.0
Pressure	Bar	23.4	16.5	1.0	2.2	2.1	11.9	1.0	2.2	1.0	1.0
Mass flow	kg/hr	15,738	114,335	69,796	4,157,164	4,227,194	3,640	73,660	73,660	267,201	704,033
Molar flow	kmol/hr	277	4,075	2,321	230,758	234,645	202	4,089	4,089	14,832	26,753
C2H6	mol %	0.10%	0.09%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C2H4	mol %	0.00%	99.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CH4	mol %	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C2H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C3H6	mol %	0.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C3H8	mol %	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H6	mol %	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H8	mol %	95.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H10	mol %	0.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C6H6	mol %	3.79%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2O	mol %	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	24.58%
O2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.84%
N2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	69.29%
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.29%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table S2. Detailed stream information according to the stream number shown in Figure S4 for No external NG case.

Name	Unit	1	2	3	4	5	6	7	8	9	10
Temperature	°C	25.0	25.0	850.0	200.0	30.0	43.0	3.0	13.0	-14.0	43.0
Pressure	Bar	1.0	1.0	2.2	2.2	2.1	38.0	34.5	4.5	23.4	23.4
Mass flow	kg/hr	220,979	564,337	295,168	295,168	225,138	221,498	200,391	21,107	184,653	15,738
Molar flow	kmol/hr	7,349	19,561	15,865	15,865	11,978	11,776	6,686	5,091	6,409	277
C2H6	mol %	100.00%	0.00%	14.65%	14.65%	19.41%	19.74%	34.75%	0.03%	36.25%	0.10%
C2H4	mol %	0.00%	0.00%	25.90%	25.90%	34.30%	34.88%	60.96%	0.64%	63.59%	0.00%
H2	mol %	0.00%	0.00%	27.40%	27.40%	36.29%	36.91%	0.00%	85.39%	0.00%	0.00%
CH4	mol %	0.00%	0.00%	4.48%	4.48%	5.93%	6.03%	0.00%	13.94%	0.01%	0.00%
C2H2	mol %	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.04%	0.00%
C3H6	mol %	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.01%	0.61%
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.10%
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
C4H8	mol %	0.00%	0.00%	1.70%	1.70%	2.25%	2.29%	4.04%	0.00%	0.10%	95.11%
C4H10	mol %	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.29%
C6H6	mol %	0.00%	0.00%	0.07%	0.07%	0.09%	0.09%	0.16%	0.00%	0.00%	3.79%
H2O	mol %	0.00%	0.00%	25.77%	25.77%	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
O2	mol %	0.00%	21.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N2	mol %	0.00%	79.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Name	Unit	11	12	13	14	15	16	17	18	19	
Temperature	°C	-35.9	25.0	15.0	30.0	43.2	25.0	263.4	25.0	25.0	
Pressure	Bar	16.5	1.0	2.2	2.1	11.9	1.0	2.2	1.0	1.0	
Mass flow	kg/hr	114,335	69,796	4,157,164	4,227,194	3,640	73,660	73,660	185,708	585,454	
Molar flow	kmol/hr	4,075	2,321	230,758	234,645	202	4,089	4,089	10,308	22,479	
C2H6	mol %	0.09%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C2H4	mol %	99.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
CH4	mol %	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C2H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C3H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C4H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C4H10	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
C6H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
H2O	mol %	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	25.97%	
O2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.83%	
N2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	68.74%	
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.46%	
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	

Table S3. Detailed stream information according to the stream number shown in Figure S7 for Electrical heating case.

Name	Unit	1	2	3	4	5	6	7	8	9	10
Temperature	°C	25.0	850.0	200.0	30.0	43.0	3.0	13.0	-14.0	43.0	-35.9
Pressure	Bar	1.0	2.2	2.2	2.1	38.0	34.5	4.5	23.4	23.4	16.5
Mass flow	kg/hr	220,979	295,168	295,168	225,138	221,498	200,391	21,107	184,653	15,738	114,335
Molar flow	kmol/hr	7,349	15,865	15,865	11,978	11,776	6,686	5,091	6,409	277	4,075
C2H6	mol %	100.00%	14.65%	14.65%	19.41%	19.74%	34.75%	0.03%	36.25%	0.10%	0.09%
C2H4	mol %	0.00%	25.90%	25.90%	34.30%	34.88%	60.96%	0.64%	63.59%	0.00%	99.90%
H2	mol %	0.00%	27.40%	27.40%	36.29%	36.91%	0.00%	85.39%	0.00%	0.00%	0.00%
CH4	mol %	0.00%	4.48%	4.48%	5.93%	6.03%	0.00%	13.94%	0.01%	0.00%	0.01%
C2H2	mol %	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.04%	0.00%	0.00%
C3H6	mol %	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.01%	0.61%	0.00%
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.10%	0.00%
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
C4H8	mol %	0.00%	1.70%	1.70%	2.25%	2.29%	4.04%	0.00%	0.10%	95.11%	0.00%
C4H10	mol %	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.29%	0.00%
C6H6	mol %	0.00%	0.07%	0.07%	0.09%	0.09%	0.16%	0.00%	0.00%	3.79%	0.00%
H2O	mol %	0.00%	25.77%	25.77%	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
O2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Name	Unit	11	12	13	14	15	16	17	18		
Temperature	°C	25.0	15.0	30.0	43.2	25.0	263.4	43.0	39.0		
Pressure	Bar	1.0	2.2	2.1	11.9	1.0	2.2	30.0	1.2		
Mass flow	kg/hr	69,796	4,157,164	4,227,194	3,640	73,660	73,660	7,448	13,659		
Molar flow	kmol/hr	2,321	230,758	234,645	202	4,089	4,089	3,695	1,396		
C2H6	mol %	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%		
C2H4	mol %	0.00%	0.00%	9.80E-07	0.00%	0.00%	0.00%	0.00%	2.34%		
H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	46.71%		
CH4	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.86%		
C2H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C3H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C4H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C4H10	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
C6H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
H2O	mol %	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00%	0.00%		
O2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
N2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%		

Table S4. Detailed stream information according to the stream number shown in Figure S10 for CCS H₂ combustion case.

Name	Unit	1	2	3	4	5	6	7	8	9	10
Temperature	°C	25.0	25.0	850.0	200.0	30.0	43.0	3.0	13.0	-14.0	43.0
Pressure	Bar	1.0	1.2	2.2	2.2	2.1	38.0	34.5	4.5	23.4	23.4
Mass flow	kg/hr	220,979	456,970	295,168	295,168	225,138	221,498	200,391	21,107	184,653	15,738
Molar flow	kmol/hr	7,349	15,836	15,865	15,865	11,978	11,776	6,686	5,091	6,409	277
C ₂ H ₆	mol %	100.00%	0.00%	14.65%	14.65%	19.41%	19.74%	34.75%	0.03%	36.25%	0.10%
C ₂ H ₄	mol %	0.00%	0.00%	25.90%	25.90%	34.30%	34.88%	60.96%	0.64%	63.59%	0.00%
H ₂	mol %	0.00%	0.00%	27.40%	27.40%	36.29%	36.91%	0.00%	85.39%	0.00%	0.00%
CH ₄	mol %	0.00%	0.00%	4.48%	4.48%	5.93%	6.03%	0.00%	13.94%	0.01%	0.00%
C ₂ H ₂	mol %	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.04%	0.00%
C ₃ H ₆	mol %	0.00%	0.00%	0.02%	0.02%	0.02%	0.02%	0.04%	0.00%	0.01%	0.61%
C ₃ H ₈	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.10%
C ₄ H ₆	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
C ₄ H ₈	mol %	0.00%	0.00%	1.70%	1.70%	2.25%	2.29%	4.04%	0.00%	0.10%	95.11%
C ₄ H ₁₀	mol %	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.29%
C ₆ H ₆	mol %	0.00%	0.00%	0.07%	0.07%	0.09%	0.09%	0.16%	0.00%	0.00%	3.79%
H ₂ O	mol %	0.00%	0.99%	25.77%	25.77%	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
O ₂	mol %	0.00%	20.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
N ₂	mol %	0.00%	77.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO ₂	mol %	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AR	mol %	0.00%	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CLYCOI	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Name	Unit	11	12	13	14	15	16	17	18	19	20
Temperature	°C	-35.9	25.0	15.0	30.0	43.2	25.0	263.4	25.0	43.0	43.0
Pressure	Bar	16.5	1.0	2.2	2.1	11.9	1.0	2.2	1.0	1.0	30.0
Mass flow	kg/hr	114,335	69,796	4,157,164	4,227,194	3,640	73,660	73,660	170,607	476,116	7,448
Molar flow	kmol/hr	4,075	2,321	230,758	234,645	202	4,089	4,089	9,470	19,176	3,695
C ₂ H ₆	mol %	0.09%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₂ H ₄	mol %	99.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H ₂	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
CH ₄	mol %	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₂ H ₂	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₃ H ₆	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₃ H ₈	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₄ H ₆	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₄ H ₈	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₄ H ₁₀	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C ₆ H ₆	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H ₂ O	mol %	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	34.34%	0.00%
O ₂	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

N2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	63.89%	0.00%
CO2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%	0.00%
CO	mol %	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AR	mol %	0.00%	0.00%	0.00%	0.00%	200.00%	0.00%	0.00%	0.00%	0.83%	0.00%
CLYCOI	mol %	0.00%	0.00%	0.00%	0.00%	300.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	400.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Name	Unit	21	22	23	24	25	26	27	28	29	30
Temperature	°C	43.0	700.0	25.0	174.8	700.0	1000.5	583.2	43.0	33.0	43.0
Pressure	Bar	30.0	33.0	1.0	28.5	28.5	28.3	28.3	27.8	30.0	153.0
Mass flow	kg/hr	13,659	32,843	60,669	13,902	13,902	46,744	46,744	38,327	11,697	26,526
Molar flow	kmol/hr	1,396	2,434	2,102	432	432	3,938	3,938	3,470	2,862	603
C2H6	mol %	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C2H4	mol %	2.34%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2	mol %	46.71%	24.55%	0.00%	0.00%	0.00%	54.80%	54.80%	76.83%	93.16%	0.00%
CH4	mol %	50.86%	31.82%	0.00%	0.00%	0.00%	0.86%	0.86%	0.97%	1.17%	0.07%
C2H2	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C3H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C3H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H8	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C4H10	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C6H6	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2O	mol %	0.00%	43.49%	0.99%	0.00%	0.00%	24.90%	24.90%	0.14%	0.00%	0.00%
O2	mol %	0.00%	0.00%	20.74%	95.04%	95.04%	0.00%	0.00%	0.00%	0.00%	0.00%
N2	mol %	0.00%	0.00%	77.32%	1.78%	1.78%	0.20%	0.20%	0.22%	0.27%	0.00%
CO2	mol %	0.00%	0.12%	0.03%	0.00%	0.00%	4.10%	4.10%	19.31%	2.34%	99.92%
CO	mol %	0.00%	0.01%	0.00%	0.00%	0.00%	14.80%	14.80%	2.13%	2.58%	0.00%
AR	mol %	0.00%	0.00%	0.92%	3.18%	3.18%	0.35%	0.35%	0.40%	0.48%	0.01%
CLYCOI	mol %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	mol %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table S5. Molecular reaction scheme for ethane cracker. The kinetic data referenced from ¹⁻⁵

No.	Reactions	Pre-exponential Constant [s ⁻¹ or ^a kmol ⁻¹ m ³ s ⁻¹]	Activation Energy [kJ/mol]
1	$C_2H_6 \leftrightarrow C_2H_4 + H_2$	(Forward) 4.60×10^{13} (Reverse) 8.49×10^8	(Forward) 272.8 (Reverse) 136.5
2	$C_3H_6 \leftrightarrow C_2H_2 + CH_4$	(Forward) 9.81×10^8 (Reverse) 5.87×10^4	(Forward) 154.5 (Reverse) 29.4
3	$C_2H_2 + C_2H_4 \rightarrow C_4H_6$	^a 1.03×10^{12}	172.6
4	$C_2H_4 + C_4H_6 \rightarrow C_6H_6 + 2H_2$	^a 8.30×10^{12}	144.6
5	$C_3H_8 \leftrightarrow C_3H_6 + H_2$	(Forward) 5.80×10^{10} (Reverse) 9.03×10^5	(Forward) 214.6 (Reverse) 93.5
6	$C_3H_8 + C_2H_4 \rightarrow C_2H_6 + C_3H_6$	^a 2.50×10^{16}	247.1
7	$2C_3H_6 \rightarrow 3C_2H_4$	7.30×10^{12}	268.5
8	$2C_2H_6 \rightarrow C_3H_8 + CH_4$	3.80×10^{11}	273.0
9	$C_4H_{10} \leftrightarrow C_4H_8 + H_2$	(Forward) 1.60×10^{12} (Reverse) 1.78×10^7	(Forward) 260.9 (Reverse) 135.1
10	$C_2H_4 + C_2H_6 \rightarrow C_3H_6 + CH_4$	^a 7.08×10^{13}	252.8
11	$C_3H_6 + C_2H_6 \rightarrow C_4H_8 + CH_4$	^a 1.00×10^{17}	251.1
12	$C_3H_8 \rightarrow C_2H_4 + CH_4$	4.90×10^{10}	212.0
13	$2C_2H_6 \rightarrow C_2H_4 + 2CH_4$	6.37×10^{23}	530.0

Table S6. Total plant cost breakdown, installation factor and scaling exponent for Baseline case.

Reaction area	Major equipment name	Major equipment installed cost	Installation factor	Scaling exponent	References
A1 Ethane cracking process	Water pump	\$ 13,154	3.10	0.80	6
	Ethane preheater	\$ 11,098,183	2.47	0.60	7
	HRSR	\$ 1,463,457	2.47	0.60	8
	Heater	\$ 4,816,879	2.47	0.60	7
	Cracker	\$ 370,332,924	2.47	0.67	9
	Quench	\$ 12,030,723	4.63	0.70	10
	Ethane compressor	\$ 7,199,401	2.47	0.80	10
	Syngas compressor	\$ 35,294,253	2.47	0.80	10
	Dryer	\$ 550,730	2.00	0.70	8
A2 Hydrocarbon fractionation	Chiller	\$ 3,992,589	3.23	0.70	8
	Cooling recycler and cooler	\$ 22,181	3.02	0.60	11
	Flasher separator	\$ 291,969	3.02	0.60	11
	Heat exchanger	\$ 2,908,179	3.71	0.00	8
	Syngas compressor	\$ 1,198,112	2.47	0.80	10
	First de-methane separator unit	\$ 2,962,789	2.47	0.65	12
	Second de-methane separator unit	\$ 2,771,687	2.47	0.65	12
	Third ethylene separator unit	\$ 12,330,702	2.47	0.65	12
	C3+ Coolers	\$ 506,948	1.50	0.65	13
A3 Combustion and power generation	Boiler	\$ 71,182,164	2.07	0.60	6
	Turbine/Generator	\$ 34,308,161	2.07	0.60	6
	Hot Process Water Softener System	\$ 194,473	2.07	0.60	6
	Deaerator	\$ 760,440	2.07	0.60	6
A4 Utility	Cooling Towers	\$ 30,597,844	1.38	0.78	13
	Accessory Electric plant	\$ 6,077,318	1.38	0.65	13
	Wastewater Treatment Equipment	\$ 13,139,010	1.44	0.00	13
Total	Total	\$ 626,044,269			

Table S7. Total plant cost breakdown, installation factor and scaling exponent for No external NG case.

Reaction area	Major equipment name	Major equipment installed cost [S]	Installation factor	Scaling exponent	References
A1 Ethane cracking process	Water pump	\$ 13,154	3.10	0.80	6
	Ethane preheater	\$ 11,098,183	2.47	0.60	7
	HRSR	\$ 1,463,457	2.47	0.60	8
	Heater	\$ 4,816,879	2.47	0.60	7
	Cracker	\$ 370,332,924	2.47	0.67	9
	Quench	\$ 12,030,723	4.63	0.70	10
	Ethane compressor	\$ 7,199,401	2.47	0.80	10
	Syngas compressor	\$ 35,294,253	2.47	0.80	10
	Dryer	\$ 550,730	2.00	0.70	8
A2 Hydrocarbon fractionation	Chiller	\$ 3,992,589	3.23	0.70	8
	Cooling recycler and cooler	\$ 22,181	3.02	0.60	11
	Flasher separator	\$ 291,969	3.02	0.60	11
	Heat exchanger	\$ 2,908,179	3.71	0.00	8
	Syngas compressor	\$ 1,198,112	2.47	0.80	10
	First de-methane separator unit	\$ 2,962,789	2.47	0.65	12
	Second de-methane separator unit	\$ 2,771,687	2.47	0.65	12
	Third ethylene separator unit	\$ 12,330,702	2.47	0.65	12
A3 Combustion and power generation	C3+ Coolers	\$ 506,948	1.50	0.65	13
	Boiler	\$ 57,222,447	2.07	0.60	6
	Turbine/Generator	\$ 27,580,125	2.07	0.60	6
	Hot Process Water Softener System	\$ 156,335	2.07	0.60	6
A4 Utility	Deaerator	\$ 611,308	2.07	0.60	6
	Cooling Towers	\$ 26,025,646	1.38	0.78	13
	Accessory Electric plant	\$ 3,875,292	1.38	0.65	13
Total	Wastewater Treatment Equipment	\$ 13,139,010	1.44	0.00	13
	Total	\$ 598,395,021			

Table S8. Total plant cost breakdown, installation factor and scaling exponent for Electrical heating case.

Reaction area	Major equipment name	Major equipment installed cost	Installation factor	Scaling exponent	References
A1 Ethane cracking process	Water pump	\$ 13,154	3.10	0.80	6
	Ethane preheater	\$ 11,098,183	2.47	0.60	7
	HRS	\$ 1,463,457	2.47	0.60	8
	Heater	\$ 4,816,879	2.47	0.60	7
	Cracker	\$ 370,332,924	2.47	0.67	9
	Quench	\$ 12,030,723	4.63	0.70	10
	Ethane compressor	\$ 7,199,401	2.47	0.80	10
	Syngas compressor	\$ 35,294,253	2.47	0.80	10
	Dryer	\$ 550,730	2.00	0.70	8
A2 Hydrocarbon fractionation	Chiller	\$ 3,992,589	3.23	0.70	8
	Cooling recycler and cooler	\$ 22,181	3.02	0.60	11
	Flasher separator	\$ 291,969	3.02	0.60	11
	Heat exchanger	\$ 2,908,179	3.71	0.00	8
	Syngas compressor	\$ 1,198,112	2.47	0.80	10
	First de-methane separator unit	\$ 2,962,789	2.47	0.65	12
	Second de-methane separator unit	\$ 2,771,687	2.47	0.65	12
	Third ethylene separator unit	\$ 12,330,702	2.47	0.65	12
A3 PSA	C3+ Coolers	\$ 506,948	1.50	0.65	13
	Pressure Swing Adsorption Unit	\$ 18,348,708	2.47	0.60	10
A4 Utility	Compressor	\$ 3,665,915	2.47	0.65	10
	Cooling Towers	\$ 7,964,133	1.38	0.78	13
	Accessory Electric plant	\$ 21,071,096	1.38	0.65	13
Total	Wastewater Treatment Equipment	\$ 13,139,010	1.44	0.00	13
	Total	\$ 533,973,722			

Table S9. Total plant cost breakdown, installation factor and scaling exponent for CCS H₂ combustion case.

Reaction area	Major equipment name	Major equipment installed cost	Installation factor	Scaling exponent	References
A1 Ethane cracking process	Water pump	\$ 13,154	3.10	0.80	6
	Ethane preheater	\$ 11,098,183	2.47	0.60	7
	HRSR	\$ 1,463,457	2.47	0.60	8
	Heater	\$ 4,816,879	2.47	0.60	7
	Cracker	\$ 370,332,924	2.47	0.67	9
	Quench	\$ 12,030,723	4.63	0.70	10
	Ethane compressor	\$ 7,199,401	2.47	0.80	10
	Syngas compressor	\$ 35,294,253	2.47	0.80	10
	Dryer	\$ 550,730	2.00	0.70	8
A2 Hydrocarbon fractionation	Chiller	\$ 3,992,589	3.23	0.70	8
	Cooling recycler and cooler	\$ 22,181	3.02	0.60	11
	Flasher separator	\$ 291,969	3.02	0.60	11
	Heat exchanger	\$ 2,177,729	3.71	0.60	8
	Syngas compressor	\$ 1,198,112	2.47	0.80	10
	First de-methane separator unit	\$ 2,962,789	2.47	0.65	12
	Second de-methane separator unit	\$ 2,771,687	2.47	0.65	12
	Third ethylene separator unit	\$ 12,330,702	2.47	0.65	12
	C3+ Coolers	\$ 506,948	1.50	0.65	13
A3 Combustion and power generation and PSA/ATR/WGS/CCS	Pressure Swing Adsorption Unit	\$ 18,348,708	2.47	0.60	10
	Compressor	\$ 6,303,329	2.47	0.65	10
	Heat exchanger	\$ 7,303,434	3.71	0.60	8
	Pre-reformer	\$ 776,030	1.50	0.70	13
	Autothermal Reformer	\$ 2,425,117	1.50	0.70	13
	Air Blower	\$ 147,044	1.38	0.65	13
	Air Separation Unit/Oxidant Compression	\$ 45,754,351	1.20	0.70	13
	Water Gas Shift (WGS) Reactors	\$ 4,037,642	1.44	0.65	13
	CO2 Glycol separation	\$ 12,658,113	1.79	0.65	14
	Gas cooler	\$ 1,732,400	3.71	0.65	8
	Dryer	\$ 128,239	2.30	0.60	8
	O2 compressor	\$ 2,073,831	2.47	0.80	10
	Water pump	\$ 30,239	3.10	0.80	6
	Boiler	\$ 33,767,283	2.07	0.60	6
	Turbine/Generator	\$ 16,746,855	2.07	0.60	6
	Hot Process Water Softener System	\$ 92,254	2.07	0.60	6
	Deaerator	\$ 360,736	2.07	0.60	6
A4 Utility	Cooling Towers	\$ 28,152,226	1.38	0.78	13
	Accessory Electric plant	\$ 1,063,871	1.38	0.65	13
	Wastewater Treatment Equipment	\$ 13,139,010	1.44	0.00	13
Total	Total	\$ 664,095,121			

Table S10. Financial input and assumption.¹⁵

Parameter	Values
Operating Capacity Factor (%)	90.0
Plant Design Capacity (million tonnes per year)	1.00
Plant Output (million tonnes per year)	0.90
Reference Year	2019
Assumed Start-up year	2018
Length of Construction Period (years)	3
% of Capital Spent in 1 st Year of Construction	8%
% of Capital Spent in 2 nd Year of Construction	60%
% of Capital Spent in 3 rd Year of Construction	32%
Start-up Time (years)	1
Plant Life (years) = Analysis Period	40
Depreciation Schedule Length (years)	20
Depreciation Type	MACRS
% Equity Financing	40
Interest Rate on Debt (%)	3.7
Debt Period (years)	Constant Debt
% of Fixed Operating Costs During Start-up (%)	75%
% of Revenues During Start-up (%)	50%
% of Variable Operating Costs During Start-up (%)	75%
Decommissioning costs (% of depreciable capital investment)	10%
Salvage value (% of total capital investment)	10%
Inflation rate (%)	1.9%
After-tax Real IRR (%)	8.0%
State Taxes (%)	6.0%
Federal Taxes (%)	21.0%
Total Tax Rate (%)	25.74%
Working Capital (% of yearly change in operating costs)	15%

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