

Supplementary material/data

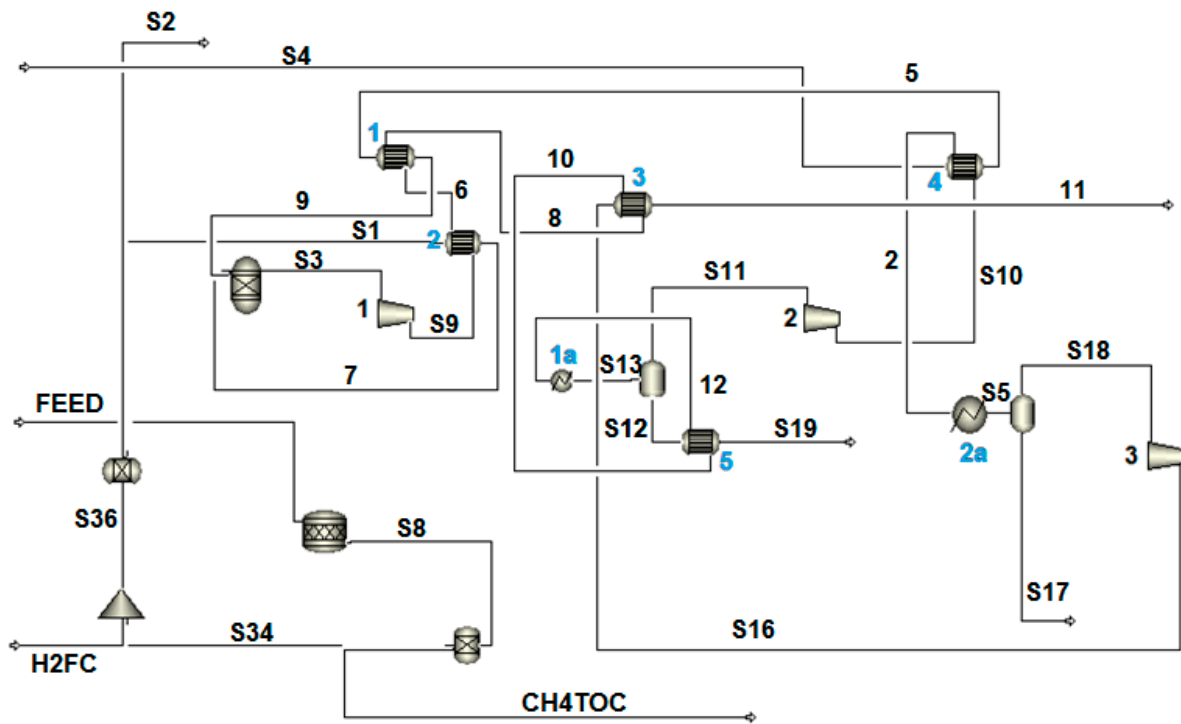


Figure S.1 Plasma assisted DMR process simulation; in black: the process streams; in blue: the heat exchangers and the refrigeration systems

Table S1. Mass and energy balances for all the streams of plasma assisted DMR process

	Units	10	11	12	2	5	6	7
From		B18	B18	B19	B6	B6	B16	B16
To		B19		B9	B4	B17	B17	B7
Substream: MIXED								
Phase:		Vapor	Vapor	Vapor	Vapor	Liquid	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	322.0	23.9	322.0	321.1	0.0	322.0	286.2
CO	kmol/h	587.1	580.9	587.1	587.1	0.0	587.1	289.0
HYDROGEN	kmol/h	1241.6	1241.3	1241.6	1241.6	0.0	1241.6	320.9
METHANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	248.0
ETHANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	2.5
ETHYLENE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	6.3
ACETYLEN	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	33.8
PROPANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.3
H ₂ O	kmol/h	1116.2	0.0	1116.2	2.8	1350.0	1116.2	136.0
Component Mass Flow								
CO ₂	kg/h	14171.4	1050.6	14171.4	14131.7	0.0	14171.4	12594.6
CO	kg/h	16444.8	16272.5	16444.8	16443.6	0.0	16444.8	8095.0
HYDROGEN	kg/h	2502.9	2502.4	2502.9	2502.8	0.0	2502.9	646.9
METHANE	kg/h	0.2	0.2	0.2	0.2	0.0	0.2	3978.5
ETHANE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	75.2
ETHYLENE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	175.3
ACETYLEN	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	878.8
PROPANE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	13.8
H ₂ O	kg/h	20109.5	0.0	20109.5	51.1	24320.6	20109.5	2450.1
Mole Flow	kmol/h	3267.0	1846.2	3267.0	2152.6	1350.0	3267.0	1322.9
Mass Flow	kg/h	53228.8	19825.6	53228.8	33129.3	24320.6	53228.8	28908.2
Volume Flow	m ³ /h	25059.6	2736.1	23952.3	3843.7	33.6	80248.5	140011.0
Temperature	°C	190.0	250.0	170.0	46.5	77.0	1204.9	1000.0
Pressure	bar	5.0	30.0	5.0	15.0	1.0	5.0	1.0

Table S1. Mass and energy balances for all the streams of plasma assisted DMR process (continued)

From	Units	S11	S12	S13	S16	S17	S18	S19
To		B2	B2	B9	B13	B14	B14	B19
		B11	B19	B2	B18		B13	
Substream: MIXED								
Phase:		Vapor	Liquid	Mixed	Vapor	Liquid	Vapor	Mixed
Component Mole Flow								
CO ₂	kmol/h	321.1	0.9	322.0	23.9	297.2	23.9	0.9
CO	kmol/h	587.1	0.0	587.1	580.9	6.1	580.9	0.0
HYDROGEN	kmol/h	1241.6	0.0	1241.6	1241.3	0.2	1241.3	0.0
METHANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETHANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETHYLENE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ACETYLEN	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROPANE	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H ₂ O	kmol/h	2.8	1113.4	1116.2	0.0	2.8	0.0	1113.4
Component Mass Flow								
CO ₂	kg/h	14131.7	39.7	14171.4	1050.6	13081.1	1050.6	39.7
CO	kg/h	16443.6	1.2	16444.8	16272.5	171.1	16272.5	1.2
HYDROGEN	kg/h	2502.8	0.1	2502.9	2502.4	0.4	2502.4	0.1
METHANE	kg/h	0.2	0.0	0.2	0.2	0.0	0.2	0.0
ETHANE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETHYLENE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ACETYLEN	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROPANE	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H ₂ O	kg/h	51.1	20058.4	20109.5	0.0	51.1	0.0	20058.4
Mole Flow	kmol/h	2152.6	1114.4	3267.0	1846.2	306.4	1846.2	1114.4
Mass Flow	kg/h	33129.3	20099.5	53228.8	19825.6	13303.7	19825.6	20099.5
Volume Flow	m ³ /h	9797.0	26.2	9823.2	1182.3	10.7	1771.9	26.9
Temperature	°C	0.0	0.0	0.0	-47.9	-100.0	-100.0	25.0
Pressure	bar	5.0	5.0	5.0	30.0	15.0	15.0	5.0

Table S1. Mass and energy balances for all the streams of plasma assisted DMR process (continued)

	Units	S2	S3	S34	S36	S4	S5	S8	S9
From		B1	B7	B26	B27		B4	B8	B3
To			B3	B27	B1	B6	B14	B26	B16
Substream: MIXED									
Phase:		Vapor	Vapor	Vapor	Vapor	Liquid	Mixed	Vapor	Vapor
Component Mole Flow									
CO ₂	kmol/h	0.0	322.0	286.2	286.2	0.0	321.1	355.5	322.0
CO	kmol/h	0.0	587.1	289.0	289.0	0.0	587.1	289.0	587.1
HYDROGEN	kmol/h	85.0	1241.6	405.9	405.9	0.0	1241.6	405.9	1241.6
METHANE	kmol/h	0.0	0.0	248.0	248.0	0.0	0.0	269.6	0.0
ETHANE	kmol/h	0.0	0.0	2.5	2.5	0.0	0.0	2.5	0.0
ETHYLENE	kmol/h	0.0	0.0	6.3	6.3	0.0	0.0	6.3	0.0
ACETYLEN	kmol/h	0.0	0.0	33.8	33.8	0.0	0.0	33.8	0.0
PROPANE	kmol/h	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.0
H ₂ O	kmol/h	0.0	1116.2	0.0	136.0	1350.0	2.8	0.0	1116.2
Component Mass Flow									
CO ₂	kg/h	0.0	14171.4	12594.6	12594.6	0.0	14131.7	15645.5	14171.4
CO	kg/h	0.0	16444.8	8095.0	8095.0	0.0	16443.6	8095.0	16444.8
HYDROGEN	kg/h	171.3	2502.9	818.2	818.2	0.0	2502.8	818.2	2502.9
METHANE	kg/h	0.0	0.2	3978.5	3978.5	0.0	0.2	4324.5	0.2
ETHANE	kg/h	0.0	0.0	75.2	75.2	0.0	0.0	75.2	0.0
ETHYLENE	kg/h	0.0	0.0	175.3	175.3	0.0	0.0	175.3	0.0
ACETYLEN	kg/h	0.0	0.0	878.8	878.8	0.0	0.0	878.8	0.0
PROPANE	kg/h	0.0	0.0	13.8	13.8	0.0	0.0	13.8	0.0
H ₂ O	kg/h	0.0	20109.5	0.0	2450.1	24320.6	51.1	0.0	20109.5
Mole Flow	kmol/h	85.0	3267.0	1271.9	1407.9	1350.0	2152.6	1362.8	3267.0
Mass Flow	kg/h	171.3	53228.8	26629.5	29079.5	24320.6	33129.3	30026.3	53228.8
Volume Flow	m ³ /h	3345.1	345772.0	50038.7	55372.7	32.3	1782.5	53609.7	99067.2
Temperature	°C	200.0	1000.0	200.0	200.0	25.0	-100.0	200.0	1551.8
Pressure	bar	1.0	1.0	1.0	1.0	1.0	15.0	1.0	5.0

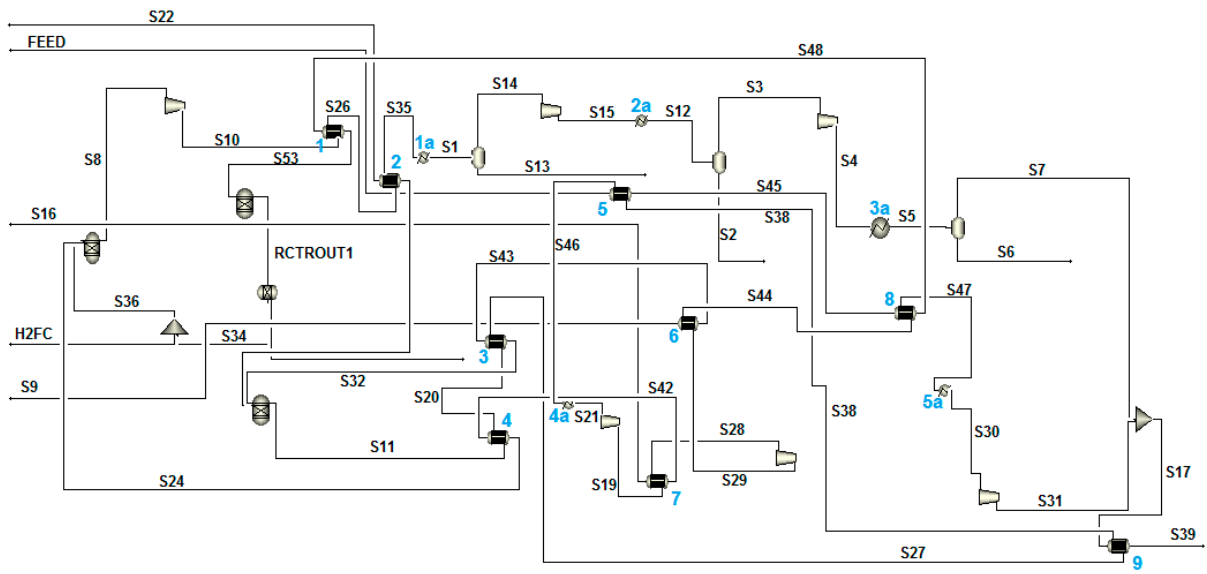


Figure S2. Thermal catalytic DMR process simulation (combined DMR and SMR); in black: the process streams; in blue: the heat exchangers and the refrigeration systems

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process

	Units	CH4TOC	FEED	H2FC	RCTROUT1	S1	S10	S11
From		B26			B8	B1	B11	B7
To			B33	B27	B26	B13	B21	B6
Substream: MIXED								
Phase:		Vapor	Vapor	Vapor	Vapor	Mixed	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	0.0	312.5	0.0	29.9	175.9	175.9	1.6
CO	kmol/h	0.0	0.0	0.0	544.3	438.4	438.4	645.0
H ₂ O	kmol/h	0.0	0.0	0.0	20.9	237.4	237.4	8.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	0.0	0.0	13.0	502.5	781.7	781.7	1941.5
METHANE	kmol/h	4.1	312.5	0.0	50.8	6.6	6.6	9.6
Component Mass Flow								
CO ₂	kg/h	0.0	13753.1	0.0	1314.9	7739.4	7739.4	71.0
CO	kg/h	0.0	0.0	0.0	15246.4	12280.9	12280.9	18067.6
H ₂ O	kg/h	0.0	0.0	0.0	377.1	4275.9	4275.9	144.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	0.0	0.0	26.2	1012.9	1575.9	1575.9	3913.9
METHANE	kg/h	65.2	5013.4	0.0	815.1	106.5	106.5	154.1
Mole Flow	kg/h	4.1	625.0	13.0	1148.4	1640.0	1640.0	2605.8
Mass Flow	kg/h	65.2	18766.4	26.2	18766.4	25978.6	25978.6	22350.6
Volume Flow	m ³ /h	345.9	15450.5	1106.1	97721.5	6895.0	44037.1	275912.0
Temperature	°C	750.0	25.0	750.0	750.0	20.0	1342.1	1000.0
Pressure	bar	1.0	1.0	1.0	1.0	5.0	5.0	1.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S12	S13	S14	S15	S16	S17	S19
From		B12	B13	B13	B14		B9	B15
To		B2		B14	B12	B31	B28	B31
Substream: MIXED								
Phase:		Mixed	Liquid	Vapor	Vapor	Liquid	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	175.8	0.1	175.8	175.8	0.0	177.4	1.6
CO	kmol/h	438.4	0.0	438.4	438.4	0.0	1083.5	645.0
H ₂ O	kmol/h	7.0	230.4	7.0	7.0	402.5	8.2	8.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	781.7	0.0	781.7	781.7	0.0	2723.3	1941.5
METHANE	kmol/h	6.6	0.0	6.6	6.6	0.0	16.2	9.6
Component Mass Flow								
CO ₂	kg/h	7735.5	3.8	7735.5	7735.5	0.0	7805.8	71.0
CO	kg/h	12280.7	0.2	12280.7	12280.7	0.0	30348.3	18067.6
H ₂ O	kg/h	126.0	4149.9	126.0	126.0	7251.2	148.2	144.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	1575.9	0.0	1575.9	1575.9	0.0	5489.8	3913.9
METHANE	kg/h	106.5	0.0	106.5	106.5	0.0	260.6	154.1
Mole Flow	kg/h	1409.6	230.5	1409.6	1409.6	402.5	4008.6	2605.8
Mass Flow	kg/h	21824.6	4153.9	21824.6	21824.6	7251.2	44052.6	22350.6
Volume Flow	m ³ /h	2303.1	5.5	6889.5	3428.2	9.6	4106.8	24868.6
Temperature	°C	20.0	20.0	20.0	162.4	25.0	87.7	298.8
Pressure	bar	15.0	5.0	5.0	15.0	1.0	30.0	5.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S2	S20	S21	S22	S24	S26	S27
From		B2	B6	B20		B6	B21	B18
To			B18	B15	B29	B10	B29	B28
Substream: MIXED								
Phase:		Liquid	Vapor	Vapor	Liquid	Vapor	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	0.0	1.6	1.6	0.0	0.0	175.9	1.6
CO	kmol/h	0.0	645.0	645.0	0.0	0.0	438.4	645.0
H ₂ O	kmol/h	4.4	8.0	8.0	656.3	402.5	237.4	8.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	0.0	1941.5	1941.5	0.0	0.0	781.7	1941.5
METHANE	kmol/h	0.0	9.6	9.6	0.0	0.0	6.6	9.6
Component Mass Flow								
CO ₂	kg/h	0.2	71.0	71.0	0.0	0.0	7739.4	71.0
CO	kg/h	0.0	18067.6	18067.6	0.0	0.0	12280.9	18067.6
H ₂ O	kg/h	79.0	144.0	144.0	11822.5	7251.2	4275.9	144.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	0.0	3913.9	3913.9	0.0	0.0	1575.9	3913.9
METHANE	kg/h	0.0	154.1	154.1	0.0	0.0	106.5	154.1
Mole Flow	kg/h	4.4	2605.8	2605.8	656.3	402.5	1640.0	2605.8
Mass Flow	kg/h	79.2	22350.6	22350.6	11822.5	7251.2	25978.6	22350.6
Volume Flow	m ³ /h	0.1	247311.0	70080.8	15.7	34235.7	35173.1	177538.0
Temperature	°C	20.0	868.0	50.0	25.0	750.0	1017.0	545.9
Pressure	bar	15.0	1.0	1.0	1.0	1.0	5.0	1.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S28	S29	S3	S30	S31	S32	S33
From		B31	B23	B2	B24	B25	B18	B21
To		B23	B32	B3	B25	B9	B7	B8
Substream: MIXED								
Phase:		Vapor	Vapor	Vapor	Vapor	Vapor	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	1.6	1.6	175.8	1.6	1.6	0.0	312.5
CO	kmol/h	645.0	645.0	438.4	645.0	645.0	0.0	0.0
H ₂ O	kmol/h	8.0	8.0	2.6	8.0	8.0	0.0	0.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	1941.5	1941.5	781.7	1941.5	1941.5	0.0	0.0
METHANE	kmol/h	9.6	9.6	6.6	9.6	9.6	656.3	312.5
Component Mass Flow								
CO ₂	kg/h	71.0	71.0	7735.3	71.0	71.0	0.0	13753.1
CO	kg/h	18067.6	18067.6	12280.7	18067.6	18067.6	0.0	0.0
H ₂ O	kg/h	144.0	144.0	47.0	144.0	144.0	0.0	0.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	3913.9	3913.9	1575.9	3913.9	3913.9	0.0	0.0
METHANE	kg/h	154.1	154.1	106.5	154.1	154.1	10528.1	5013.4
Mole Flow	kg/h	2605.8	2605.8	1405.2	2605.8	2605.8	656.3	625.0
Mass Flow	kg/h	22350.6	22350.6	21745.4	22350.6	22350.6	10528.1	18766.4
Volume Flow	m ³ /h	14940.7	7454.8	2303.0	4736.0	3091.7	61137.7	53188.5
Temperature	°C	70.0	237.3	20.0	50.0	144.3	847.0	750.0
Pressure	bar	5.0	15.0	15.0	15.0	30.0	1.0	1.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S34	S35	S36	S37	S38	S39	S4
From		B26	B29	B27	B29	B28	B28	B3
To		B27	B1	B10	B7	B33		B4
Substream: MIXED								
Phase:		Vapor	Mixed	Vapor	Vapor	Vapor	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	29.9	175.9	29.9	0.0	1.6	177.4	175.8
CO	kmol/h	544.3	438.4	544.3	0.0	645.0	1083.5	438.4
H ₂ O	kmol/h	20.9	237.4	20.9	656.3	8.0	8.2	2.6
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	502.5	781.7	515.5	0.0	1941.5	2723.3	781.7
METHANE	kmol/h	46.7	6.6	46.7	0.0	9.6	16.2	6.6
Component Mass Flow								
CO ₂	kg/h	1314.9	7739.4	1314.9	0.0	71.0	7805.8	7735.3
CO	kg/h	15246.4	12280.9	15246.4	0.0	18067.6	30348.3	12280.7
H ₂ O	kg/h	377.1	4275.9	377.1	11822.5	144.0	148.2	47.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	1012.9	1575.9	1039.1	0.0	3913.9	5489.8	1575.9
METHANE	kg/h	749.9	106.5	749.9	0.0	154.1	260.6	106.5
Mole Flow	kg/h	1144.3	1640.0	1157.3	656.3	2605.8	4008.6	1405.2
Mass Flow	kg/h	18701.2	25978.6	18727.4	11822.5	22350.6	44052.6	21745.4
Volume Flow	m ³ /h	97375.6	9588.5	98482.0	69252.8	123215.0	5923.6	1492.2
Temperature	°C	750.0	86.4	750.0	996.0	295.2	250.0	103.7
Pressure	bar	1.0	5.0	1.0	1.0	1.0	30.0	30.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S42	S43	S44	S45	S46	S47	S48
From		B31	B32	B32	B33	B33	B34	B34
To		B6	B18	B34	B34	B20	B24	B21
Substream: MIXED								
Phase:		Mixed	Vapor	Vapor	Vapor	Vapor	Vapor	Vapor
Component Mole Flow								
CO ₂	kmol/h	0.0	0.0	1.6	312.5	1.6	1.6	312.5
CO	kmol/h	0.0	0.0	645.0	0.0	645.0	645.0	0.0
H ₂ O	kmol/h	402.5	0.0	8.0	0.0	8.0	8.0	0.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	0.0	0.0	1941.5	0.0	1941.5	1941.5	0.0
METHANE	kmol/h	0.0	656.3	9.6	312.5	9.6	9.6	312.5
Component Mass Flow								
CO ₂	kg/h	0.0	0.0	71.0	13753.1	71.0	71.0	13753.1
CO	kg/h	0.0	0.0	18067.6	0.0	18067.6	18067.6	0.0
H ₂ O	kg/h	7251.2	0.0	144.0	0.0	144.0	144.0	0.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	0.0	0.0	3913.9	0.0	3913.9	3913.9	0.0
METHANE	kg/h	0.0	10528.1	154.1	5013.4	154.1	154.1	5013.4
Mole Flow	kg/h	402.5	656.3	2605.8	625.0	2605.8	2605.8	625.0
Mass Flow	kg/h	7251.2	10528.1	22350.6	18766.4	22350.6	22350.6	18766.4
Volume Flow	m ³ /h	11488.0	26752.6	6494.6	19683.4	117759.0	6277.1	22015.3
Temperature	°C	99.6	217.0	171.0	106.0	270.0	156.0	150.7
Pressure	bar	1.0	1.0	15.0	1.0	1.0	15.0	1.0

Table S2. Mass and energy balances for all the streams of thermal catalytic DMR process (continued)

	Units	S5	S6	S7	S8	S9
From		B4	B5	B5	B10	
To		B5		B9	B11	B32
Substream: MIXED						
Phase:		Mixed	Liquid	Vapor	Vapor	Vapor
Component Mole Flow						
CO ₂	kmol/h	175.8	0.0	175.8	175.9	0.0
CO	kmol/h	438.4	0.0	438.4	438.4	0.0
H ₂ O	kmol/h	2.6	2.4	0.2	237.4	0.0
METHANOL	kmol/h	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kmol/h	781.7	0.0	781.7	781.7	0.0
METHANE	kmol/h	6.6	0.0	6.6	6.6	656.3
Component Mass Flow						
CO ₂	kg/h	7735.3	0.5	7734.8	7739.4	0.0
CO	kg/h	12280.7	0.0	12280.7	12280.9	0.0
H ₂ O	kg/h	47.0	42.8	4.2	4275.9	0.0
METHANOL	kg/h	0.0	0.0	0.0	0.0	0.0
HYDROGEN	kg/h	1575.9	0.0	1575.9	1575.9	0.0
METHANE	kg/h	106.5	0.0	106.5	106.5	10528.1
Mole Flow	kg/h	1405.2	2.4	1402.8	1640.0	656.3
Mass Flow	kg/h	21745.4	43.4	21702.0	25978.6	10528.1
Volume Flow	m ³ /h	1038.1	0.1	1038.1	139509.0	16243.5
Temperature	°C	-10.0	-10.0	-10.0	750.0	25.0
Pressure	bar	30.0	30.0	30.0	1.0	1.0