Supplementary Information (SI) for Sustainable Energy & Fuels.

Supporting information

Multi-stage structured catalyst system for post-treatment of GHG exhausted from industrial processes

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Figure S1 Fast Fourier Transform (FFT) patterns of as-prepared Ru/CeO_2 catalyst for CO_2 methanation.

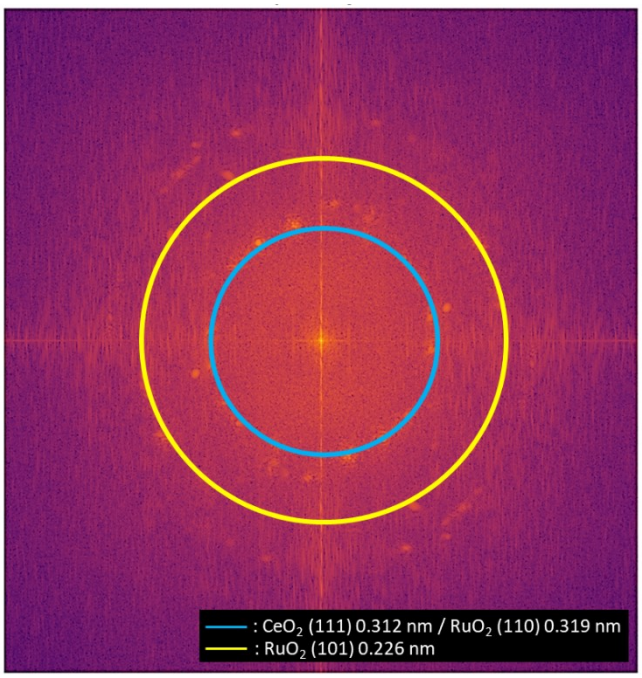


Figure S2 Fast Fourier Transform (FFT) patterns of as-prepared $Ni/CeO_2–Al_2O_3$ catalyst for DRM.

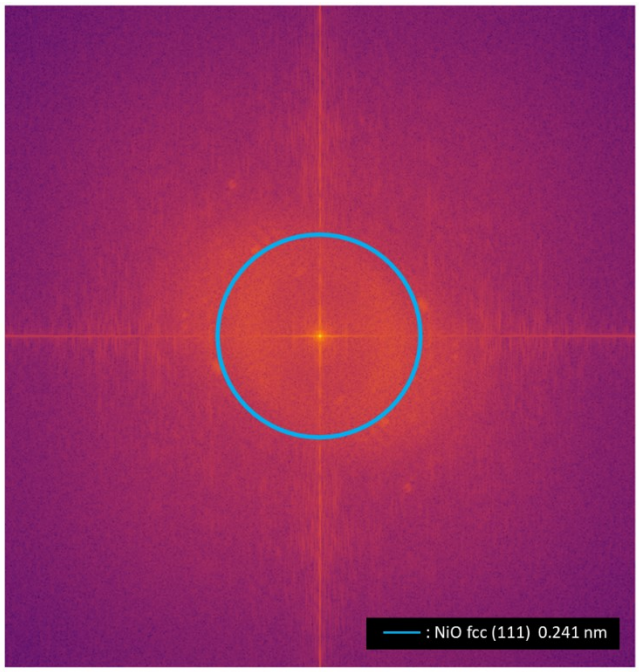
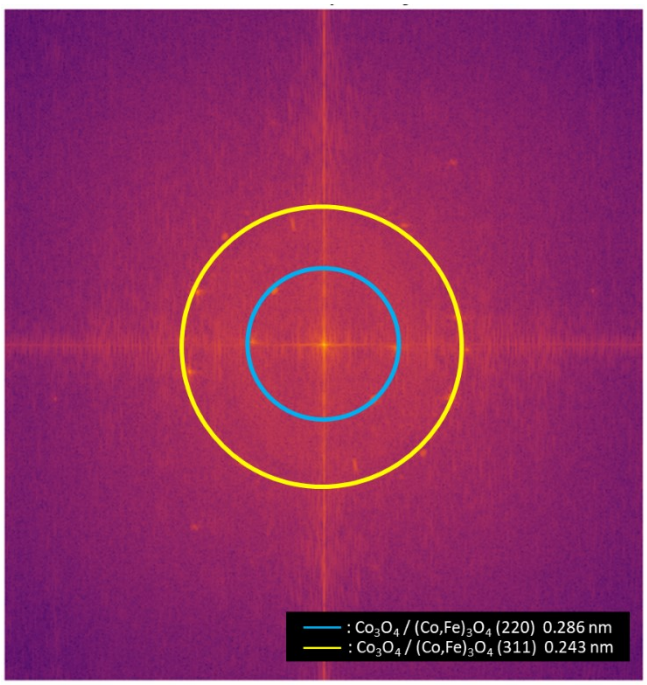


Figure S3 Fast Fourier Transform (FFT) patterns of as-prepared Fe-Co-K catalyst for carbon capture.



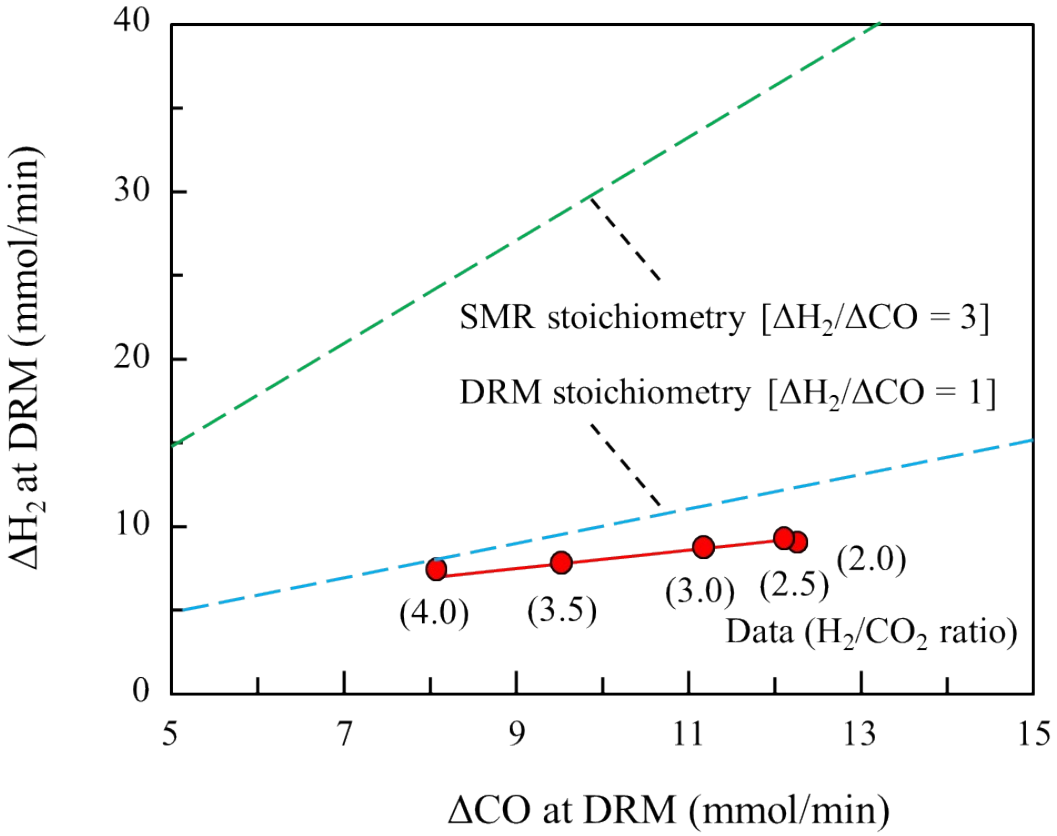


Figure S4 Incremental molar changes of H_2 (ΔH_2) plotted against those of CO (ΔCO) in the DRM reactor. Dashed lines represent the stoichiometric reference slopes for DRM ($\Delta H_2/\Delta CO = 1$, blue) and SMR ($\Delta H_2/\Delta CO = 3$, green).

Table S1 Weight change before and after boring.

	A	B	C	D	total
Amount of carbon before boring / g	2.23	1.08	0.24	0.15	3.70
Amount of carbon after boring / g	0.93	0.53	0.13	0.08	1.67
Weight change / g	-1.30	-0.55	-0.11	-0.07	-2.03

Table S2 Weight change before and after boring.

	A	B	C	D	total
Amount of carbon before boring / g	1.72	1.88	1.03	0.44	5.07
Amount of carbon after boring / g	1.41	1.36	0.53	0.11	3.41
Weight change / g	-0.31	-0.52	-0.50	-0.33	-1.66

Table S3 Amount of captured carbon removed through boring operation.

	A	B	C	D
First boring operation / g	1.30	0.55	0.11	0.07
Second boring operation / g	0.31	0.52	0.50	0.33
Total / g	1.61	1.07	0.61	0.40

Table S4 Amount of catalyst metal removed through boring operation.

Carbon capture position	Removed catalyst / mg
□□□□A	48
□□□□B	32
□□□□C	18
□□□□D	12

Figure S5 Reaction characteristic of carbon capturing system by using reuse catalyst.

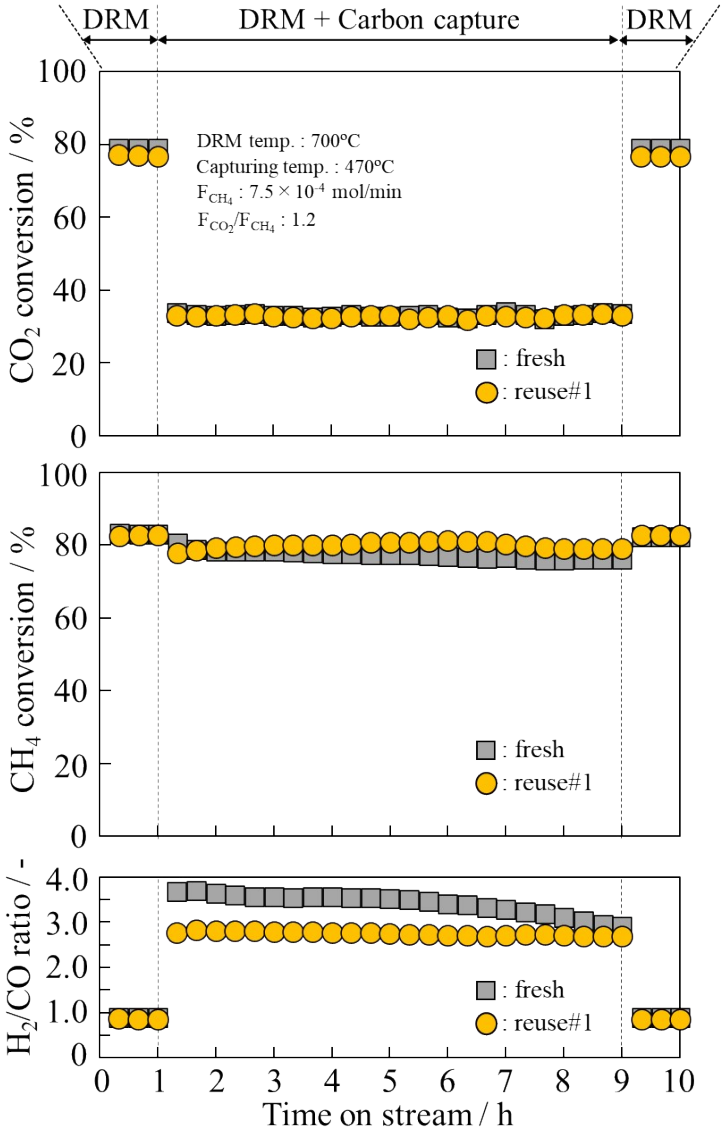


Figure S6 Amount of carbon over reuse catalyst.

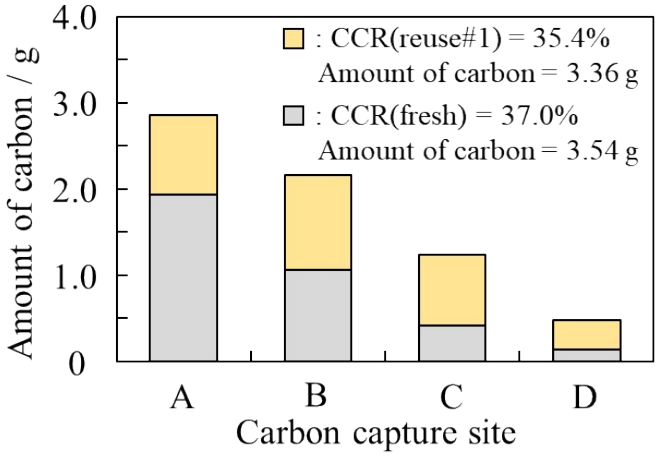


Figure S7 Captured carbon over reuse catalyst.

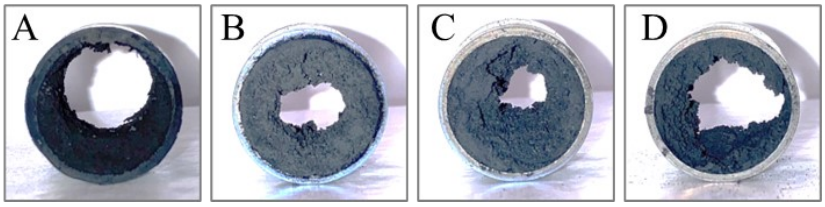


Figure S8 Reaction characteristic of carbon capturing system by using reuse#2 catalyst.

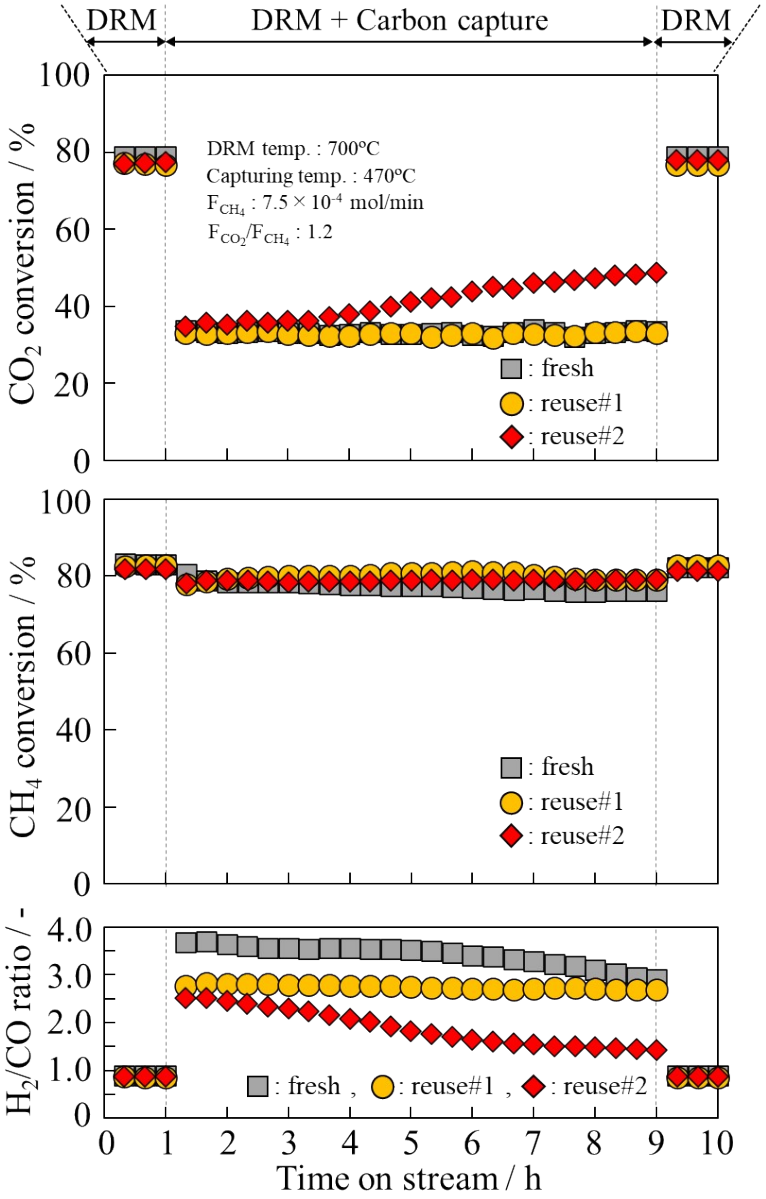


Figure S9 Amount of carbon over reuse#2 catalyst.

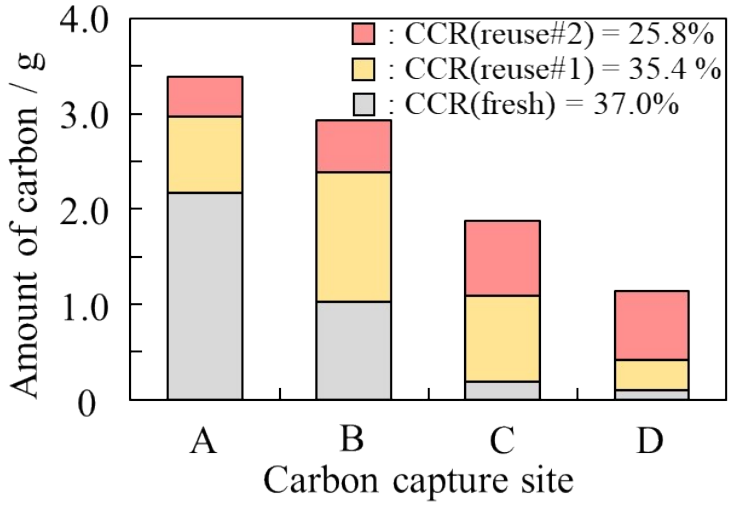


Figure S10 Captured carbon over reuse#2 catalyst.

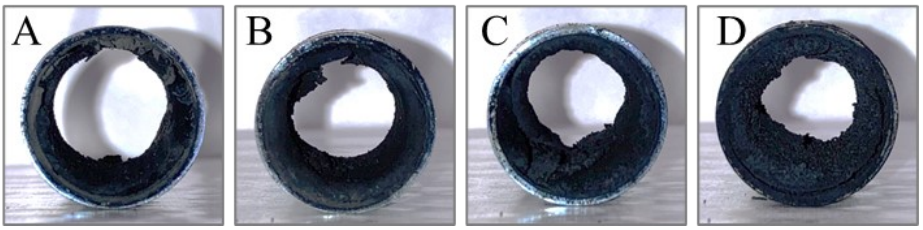


Figure S11 Weight loss curves measured by TG-DTA over captured carbon.

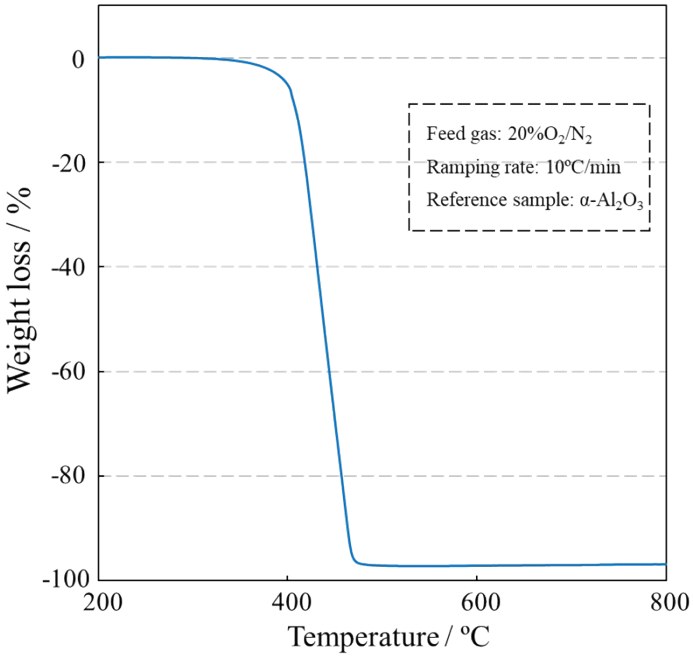


Figure S12 Reaction characteristic of carbon capturing system by using reuse#3 catalyst.

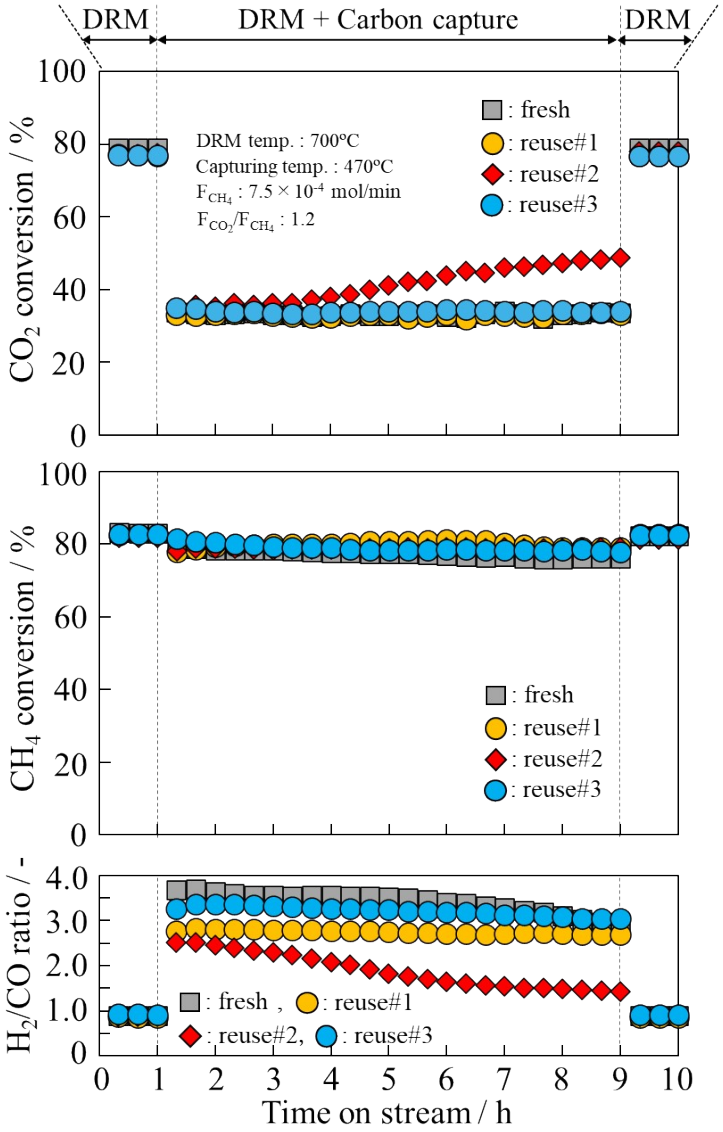


Figure S13 Amount of carbon over reuse#3 catalyst.

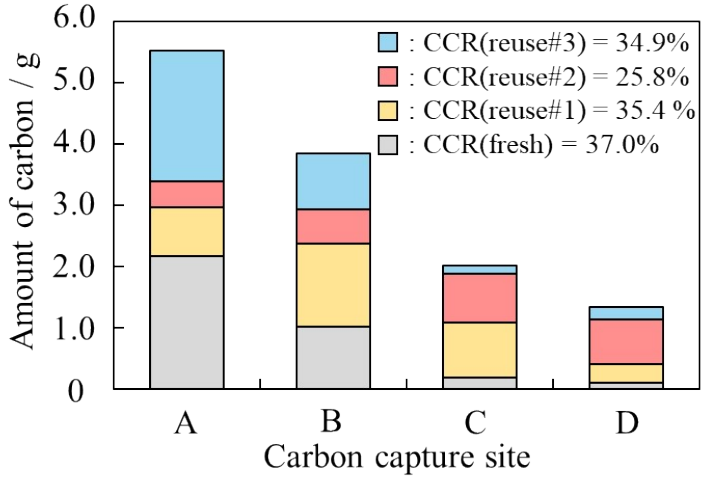


Figure S14 Captured carbon over reuse#3 catalyst.

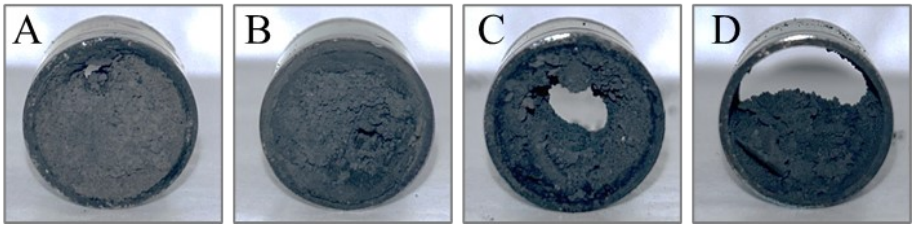


Figure S15 Overall exergy balance of the integrated methanation–DRM–carbon capture system considering external energy inputs. Exergy values at the outlet of each reaction stage are shown for H_2/CO_2 feed ratios of 2.0, 2.5, 3.0, 3.5, and 4.0.