Analysis of the performance of Air Pollution Control residues as CO_2 sorbents in the calcium looping process

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SUPPLEMENTARY MATERIAL

S1. Morphological characterization of the APC residues

Particle size distribution

Table S1-1. The table reports the particle size distribution data of the analyzed samples, expressed in terms of characteristic diameters d10, d50, and d90. The measurements were performed using a Malvern Mastersizer Hydro 2000 MU laser diffraction analyzer.

Sample	d10 [µm]	d50 [µm]	d90 [µm]
R	3.5	13.8	43.0
C1a	3.7	7.5	19.6
C1b	3.0	7.6	30.1
C1c	2.9	7.7	40.0
C1d	4.0	9.0	36.2
C2	4.2	8.4	17.6
C3	3.9	8.7	24.9
C4	4.6	10.9	37.9
W1	9.4	59.4	280.2
W2	7.7	29.6	418.5
G1	3.7	18.0	80.0

Specific surface area (S_{BET})

Table S1-2. The table reports the specific surface area of all the starting materials, measured by a N_2 adsorption instrument with a Brunauer–Emmett–Teller (BET) surface area analyser (Anton Paar NOVA 800).

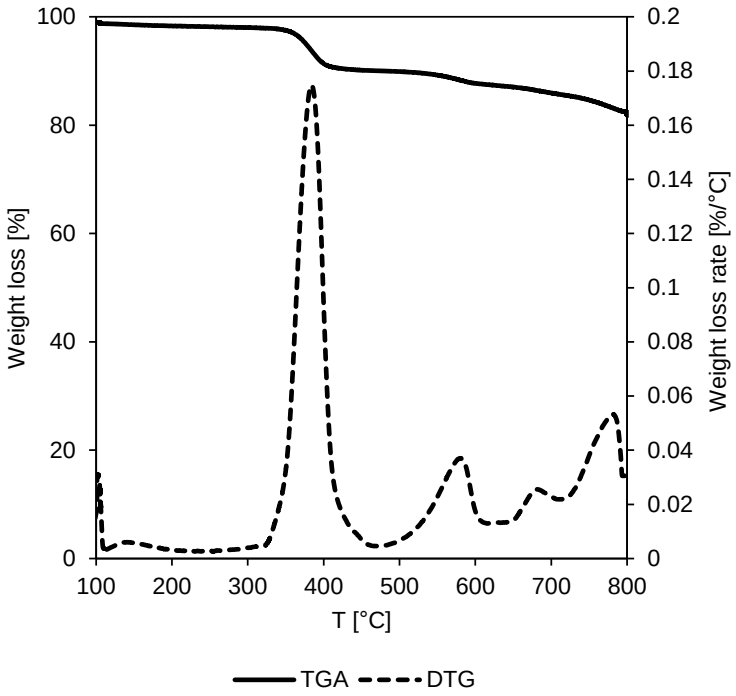
Sample	S_{BET} [m^2/g]
R	31.0
C1a	15.5
C1b	12.0
C1c	16.7
C1d	24.1
C2	9.5
C3	10.4
C4	11.1
W1	3.2
W2	3.9
G1	10.3

S2. Thermogravimetric characterization of the APC residues

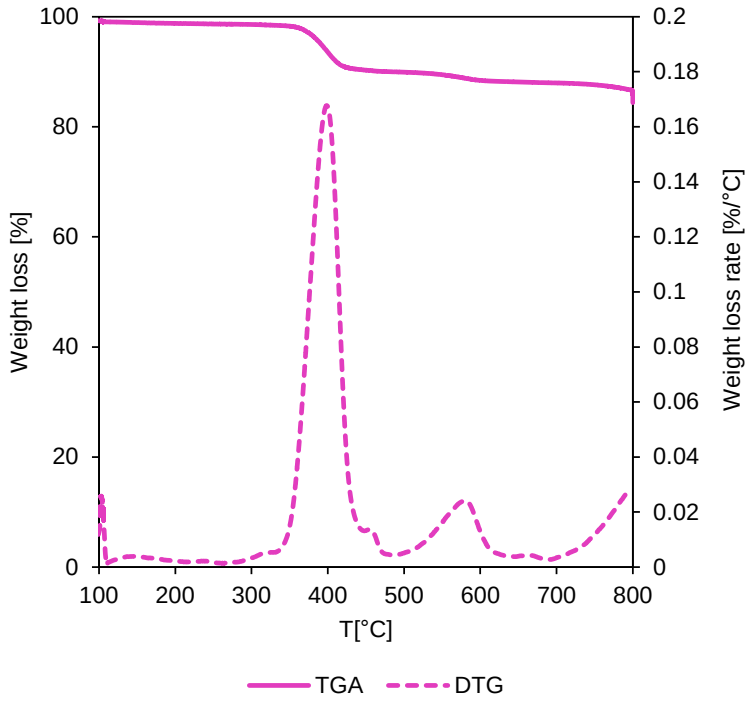
The following figures report weight loss (TGA) and weight loss rate (DTG) curves obtained for the thermal degradation of all the samples analyzed. All the TG runs were carried out according to the procedure described in Section 2.3-a of the main text.

Samples from different FGT lines of the same ceramic manufacturing plant

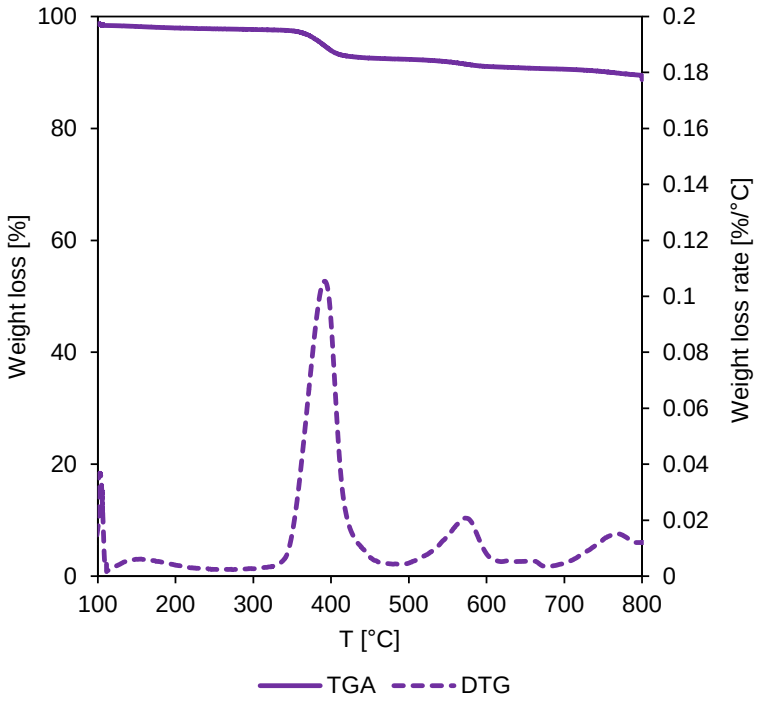
C1a



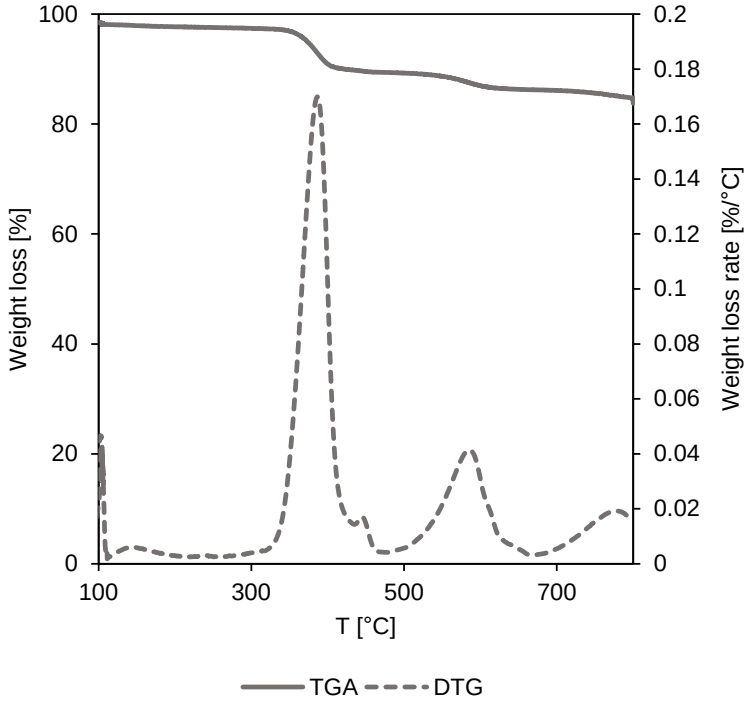
C1b



C1c


100
80
60
40
20
0
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Weight loss [%]
Weight loss rate [%/°C]
100
200
300
400
500
600
700
800
T [°C]
TGA
DTG

C1d


100
80
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40
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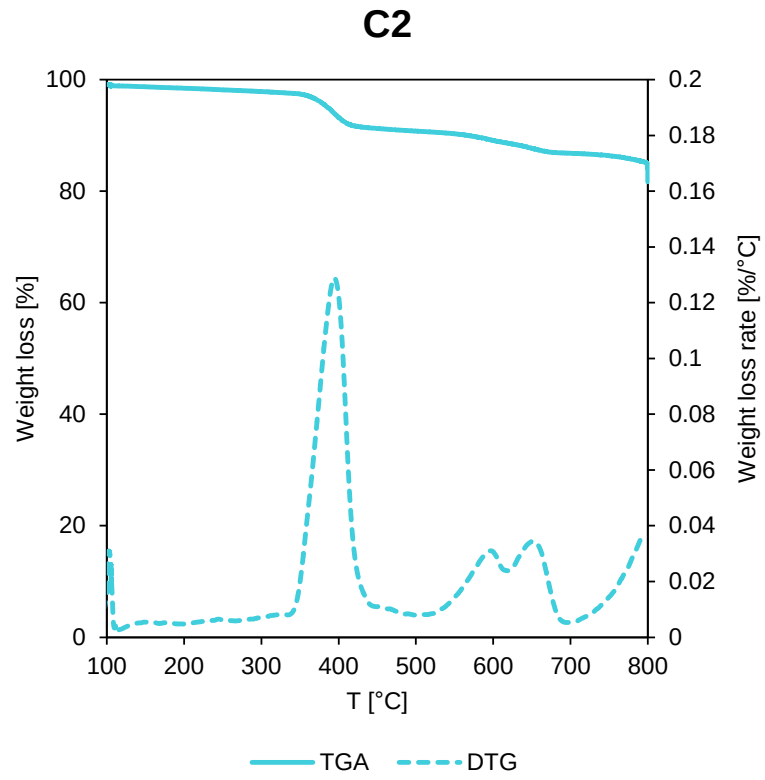
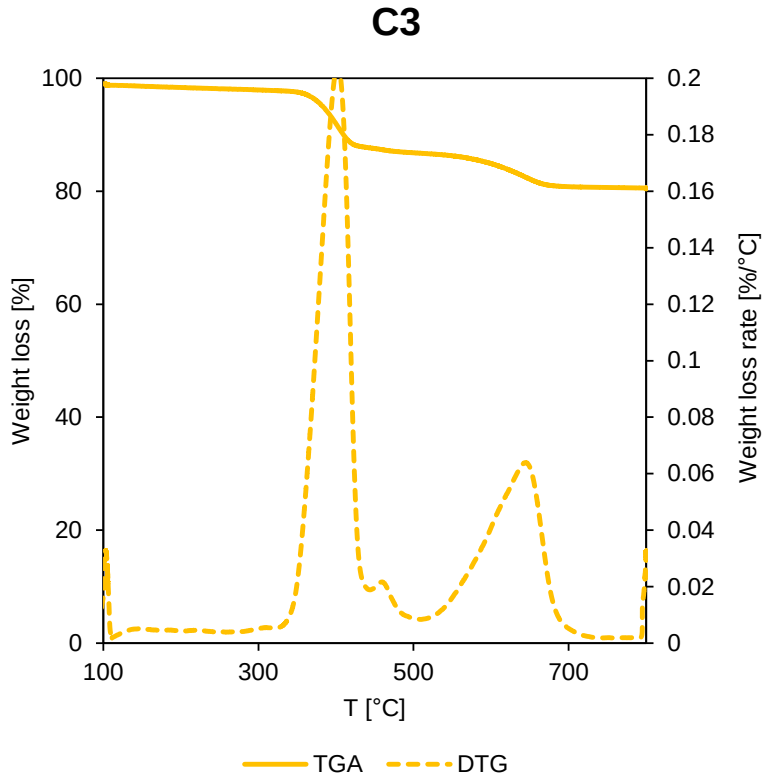
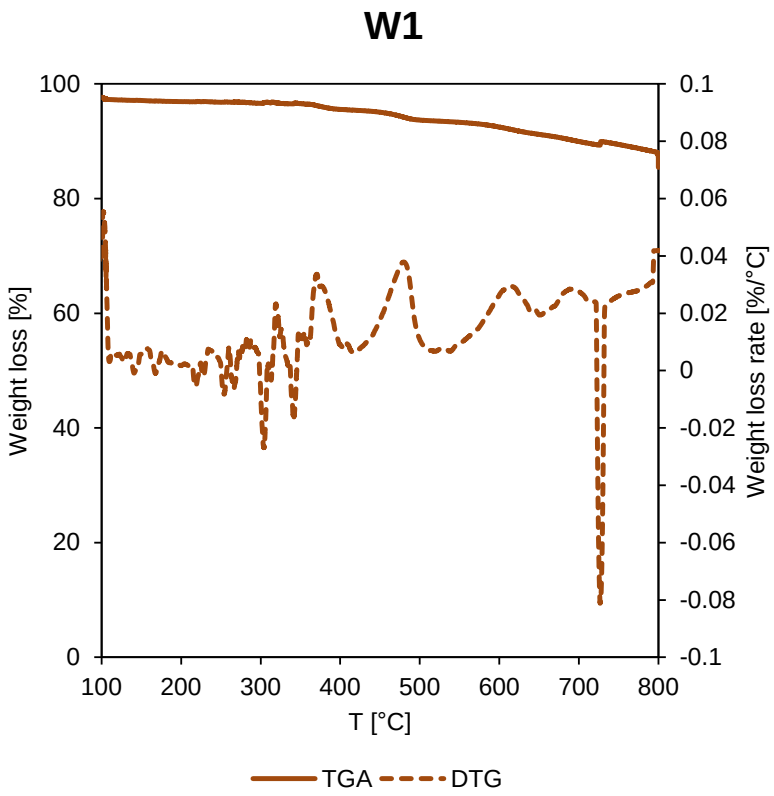
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Weight loss [%]
Weight loss rate [%/°C]
100
300
500
700
T [°C]
TGA
DTG

Samples from FGT lines of different ceramic manufacturing plants





Sample from FGT line of a WtE facility



S3. Estimated chemical composition of the APC residues

TG runs

Table S3-1. Composition of the main chemical species (% weight) in the untreated samples obtained from TG runs carried out by the procedure described in section 2.3-a of the main text. The temperature intervals (°C) considered to extract the data for each chemical species are also reported. To calculate the "dry" $Ca(OH)_2$ content (*), the weight loss referred to its dehydration is normalized considering the weight loss of the sample at 105 °C.

	Composition [% wt.]		
Sample	$Ca(OH)_2$ * **(350-450 °C)**	$CaCO_3$ **(500-800 °C)**	Others
R	76.2	16.8	7.0
C1a	28.4	20.3	51.3
C1b	30.6	12.4	57.0
C1c	17.6	8.1	74.3
C1d	29.7	13.9	56.4
C2	23.7	11.8	64.5
C3	43.5	15.8	40.6
C4	51.8	13.1	35.1
W1	8.2	12.8	79.1
W2	21.5	16.0	62.5
G1	39.0	22.4	38.6

Rietveld refinement

Table S3-2. Crystalline speciation of the untreated samples obtained through Rietveld analysis, showing the crystalline phases identified, including those composing the "Others" fraction in Table S3-1.

	Rietveld [% wt.]			
Sample	$Ca(OH)_2$	$CaCO_3$	$CaSO_4$	CaF_2
C1a	36.5	1.8	1.3	60.4
C1b	36.9	1.1	11.3	50.7
C1c	21.4	0.6	2.5	75.5
C1d	37.0	1.4	0.8	60.8
C2	28.5	2.5	3.0	66.0
C3	48.1	5.7	-	46.2
C4	65.3	2.3	11.5	20.9
G1	74.0	11.0	10.0	5.0

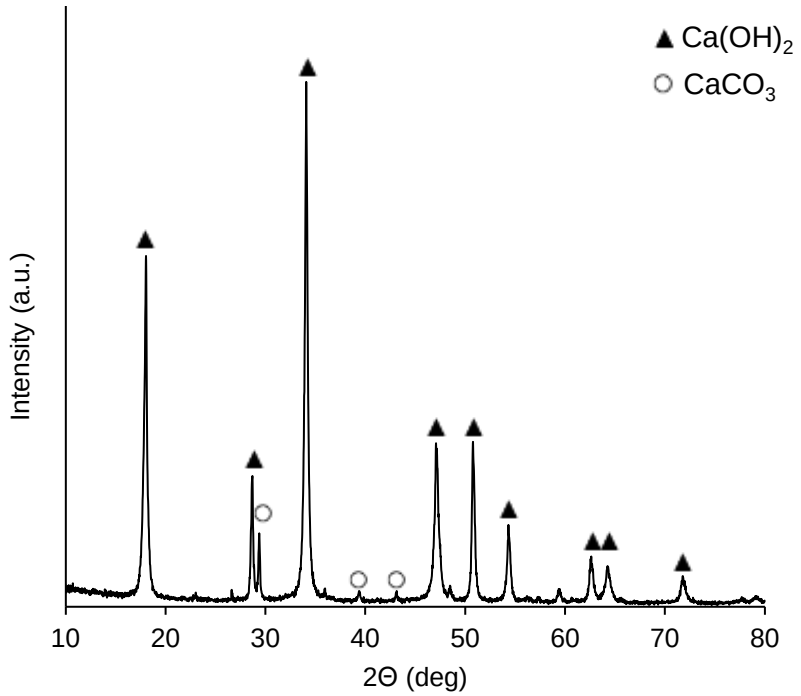


Figure S3-1. XRD analysis of the reference sample R (virgin hydrated lime).

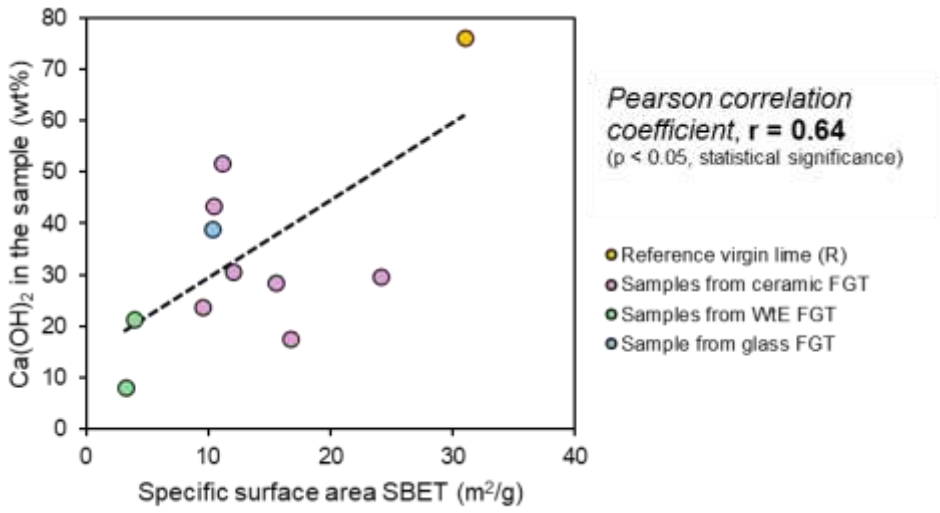


Figure S3-2. Correlation between S_{BET} of the samples determined as in Section S1 and $Ca(OH)_2$ content determined by TGA.

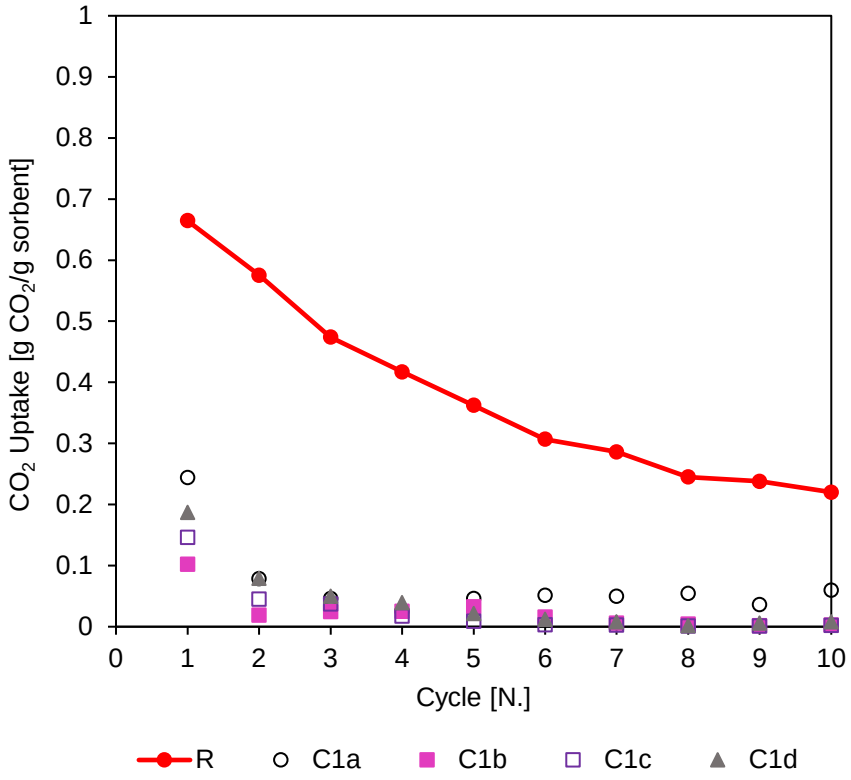
S4. CaO content in the activated samples and CO_2 uptake after different cycles

Table S4-1. Initial CaO fraction of the activated samples (η_{CaO}, Eq. 4 of the manuscript) and experimental uptake of CO_2 at the end of the experimental runs after 1, 5, and 10 cycles. Standard deviation values are reported for the obtained results.

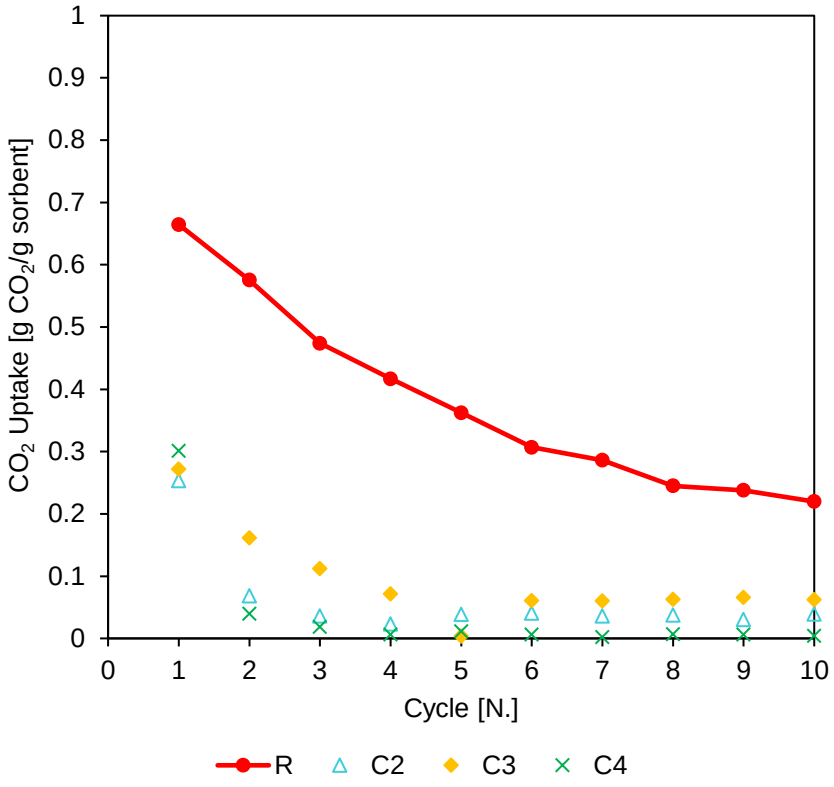
Sample	η_{CaO} (-)	CO_2 uptake [g CO_2/g sorbent]		
		cycle 1	cycle 5	cycle 10
R	0.67	0.665 ± 0.006	0.362 ± 0.012	0.220 ± 0.062
C1a	0.33	0.244 ± 0.013	0.046 ± 0.016	0.059 ± 0.008
C1b	0.30	0.102 ± 0.025	0.032 ± 0.014	0.002 ± 0.001
C1c	0.18	0.146 ± 0.016	0.009 ± 0.001	0.002 ± 0.003
C1d	0.30	0.187 ± 0.017	0.021 ± 0.009	0.008 ± 0.001
C2	0.25	0.253 ± 0.007	0.039 ± 0.013	0.039 ± 0.013
C3	0.42	0.272 ± 0.008	0.066 ± 0.010	0.062 ± 0.019
C4	0.47	0.301 ± 0.003	0.011 ± 0.007	0.004 ± 0.001
W1	0.13	0.060 ± 0.014	0.061 ± 0.033	0.028 ± 0.001
W2	0.25	0.147 ± 0.001	0.029 ± 0.002	0.028 ± 0.003
G1	0.42	0.380 ± 0.003	0.168 ± 0.010	0.142 ± 0.010

S5. Cyclic performance over 10 cycles

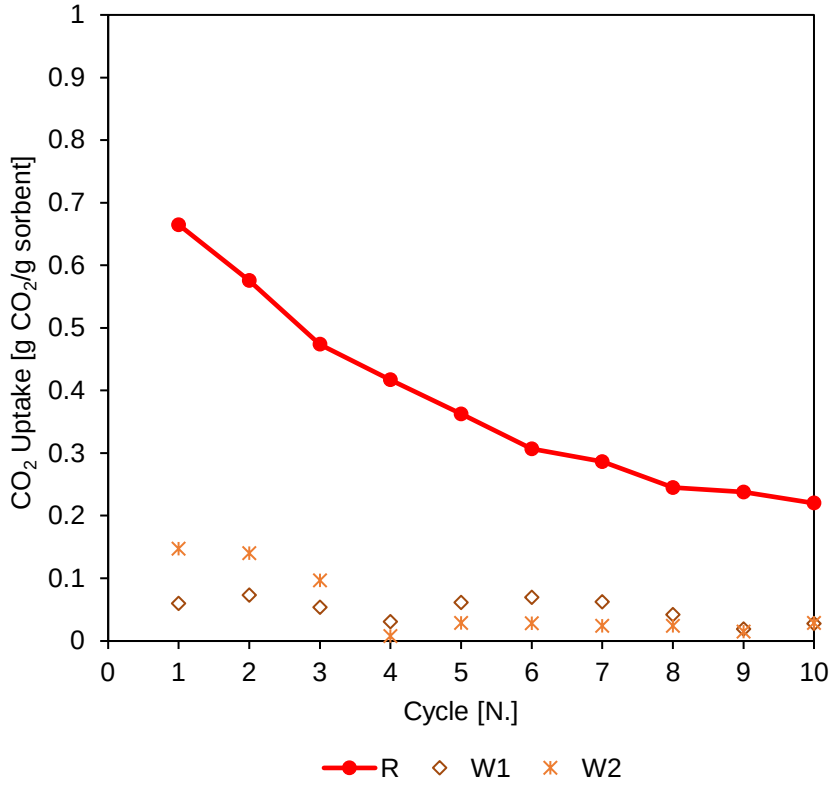
Samples from different FGT lines of the same ceramic manufacturing plant



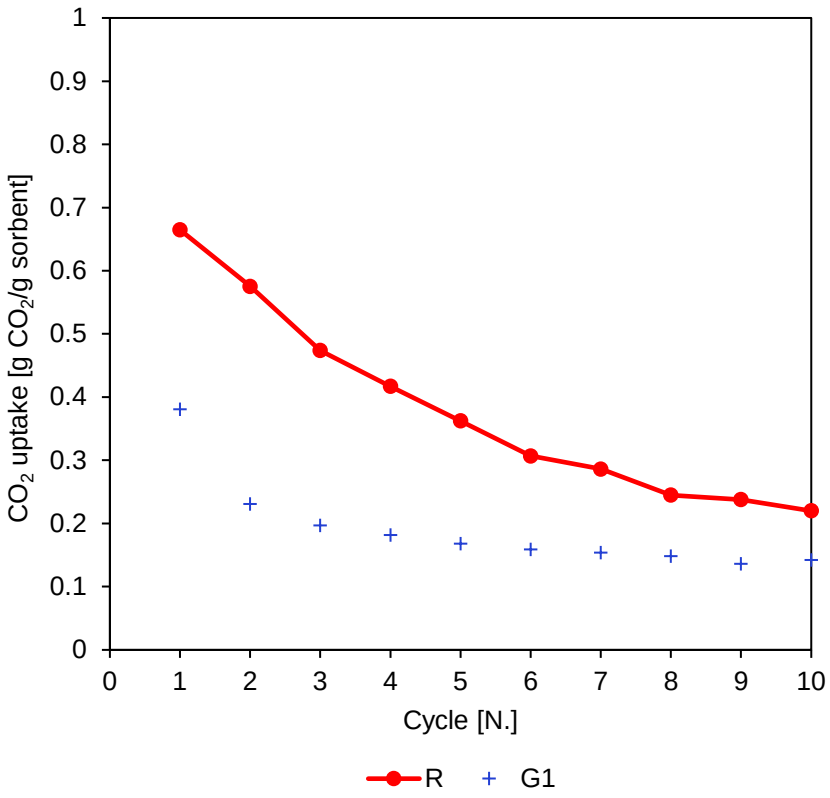
Samples from FGT lines of different ceramic manufacturing plants



Samples from FGT lines of different WtE facilities



Sample from FGT line of a glass manufacturing plant



S6. Cyclic performance over 40 cycles