Electronic Supplementary Material (ESI) for Green Chemistry.

Supporting information for

Comparative environmental assessment of zeolites synthesized from chemicals and natural minerals

Xiaoling Chen[1], Guoxi Xiao[1,2], Tiesen Li[1,2,*], Chan Wang[1,2], Qingyan Cui[1,2], Xiaojun Bao[1,2] and Yuanyuan Yue[1,2,*]

[1]*National Engineering Research Center of Chemical Fertilizer Catalyst, College of Chemical Engineering, Fuzhou University, Fuzhou 350002, P. R. China.*

[2]*Qingyuan Innovation Laboratory, Quanzhou 362801, Fujian Province, P. R. China.*

**Corresponding authors. E-mails: litiesen@fzu.edu.cn (T. Li); yueyy@fzu.edu.cn (Y. Yue).*

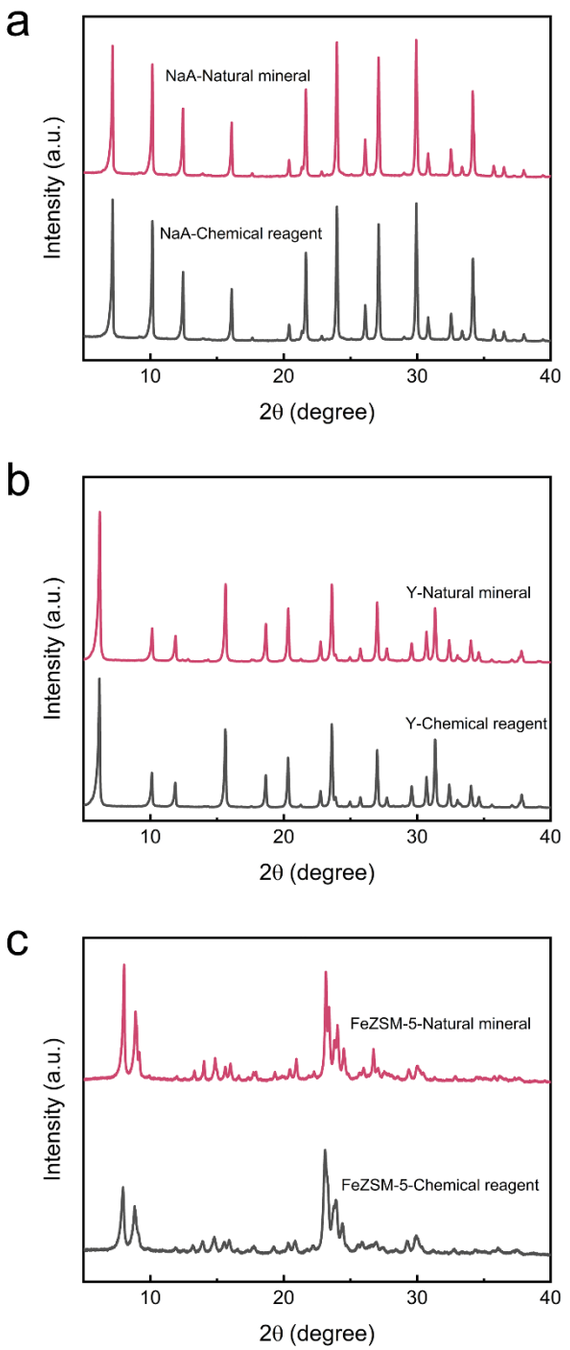

Fig. S1. XRD patterns of different (a) NaA, (b) Y and (c) FeZSM-5 zeolites.

Table S1. The transportation distance of raw materials.

Raw material	Transport distance/km
Sodium hydroixed	1149
Sodium silicate	932
Sodium aluminum	1225
Sulfuric acid	1027
Tetrapropylammonium bromide (TPABr)	460
Ferrous sulfate	1189
Kaolin	688
Diatomite	1469
Rectorite	1016

Table S2. Input and output inventories to produce one ton of NaA zeolite from chemicals.

	Category	Unit	Value	Database source
Output	NaA zeolite	ton	1.00	
Input	Sodium silicate	ton	0.44	CLCD
	Sodium aluminate	ton	0.45	Ecoinvent 3.1
	Sodium hydroxide	ton	0.95	Ecoinvent 3.1
	Synthetic water	ton	12.08	CLCD
	Washing water	ton	9.44	CLCD
	Electricity	kW·h	181.61	CLCD
	Natural gas	Nm^3	0.22	CLCD
	Transport	ton·km	113.78	CLCD
Emission	Wastewater	ton	21.41	CLCD

Table S3. Input and output inventories to produce one ton of natural mineral through dry processing route.

	Category	Unit	Value	Database source
Output	Nature mineral	ton	1.00	
	Sandstone	ton	1.92	
Input	Ore	ton	2.90	CLCD
	Synthetic water	kg	0.34	CLCD
	Electricity	kW•h	11.60	CLCD
Emission	Particulate	kg	7.96E-04	Negligible: Material with a weight ratio < 1 %

Table S4. Input and output inventories to produce one ton of NaA zeolite from natural minerals.

·Preparation of SMS-K

	Category	Unit	Value	Database source
Output	SMS-K	ton	1.00	
Input	Kaolin	ton	0.48	Foreground data
	Sodium hydroxide	ton	0.73	Ecoinvent 3.1
	Synthetic water	ton	0.68	CLCD
	Electricity	kW·h	5.00	CLCD
	Natural gas	Nm^3	58.37	CLCD
	Transport	ton·km	65.00	CLCD

·Preparation of NaA zeolite

	Category	Unit	Value	Database source
Output	NaA zeolite	ton	1.00	
Input	SMS-K	ton	1.46	Foreground data
	Synthetic water	ton	11.12	CLCD
	Washing water	ton	9.02	CLCD
	Electricity	kW·h	158.22	CLCD
	Natural gas	Nm^3	0.14	CLCD
Emission	Wastewater	ton	20.79	CLCD

Table S5. Input and output inventories to produce one ton of Y zeolite from chemicals.

·Preparation of SDA

	Category	Unit	Value	Database source
Output	SDA	ton	1.00	
Input	Sodium silicate	ton	0.16	CLCD
	Sodium aluminate	ton	0.02	Ecoinvent 3.1
	Sodium hydroxide	ton	0.12	Ecoinvent 3.1
	Synthetic water	ton	0.79	CLCD
	Electricity	kW·h	1.20	CLCD
	Transport	ton·km	10.64	CLCD

·Preparation of Y zeolite

	Category	Unit	Value	Database source
Output	Y zeolite	ton	1.00	
Input	Sodium silicate	ton	1.13	CLCD
	Sodium aluminate	ton	0.27	Ecoinvent 3.1
	SDA	ton	1.34	Foreground data
	Sulfuric acid	ton	0.10	CLCD
	Synthetic water	ton	7.12	CLCD
	Washing water	ton	9.10	CLCD
	Electricity	kW·h	175.90	CLCD
	Natural gas	Nm^3	0.31	CLCD
	Transport	ton·km	64.05	CLCD
Emission	Wastewater	ton	17.25	CLCD

Table S6. Input and output inventories to produce one ton of Y zeolite from natural minerals.

·Preparation of thermal activated diatomite (T-D)

	Category	Unit	Value	Database source
Output	T-D	ton	1.00	
Input	Diatomite	ton	1.02	Foreground data
	Natural gas	Nm^3	141.12	CLCD
	Transport	ton·km	48.97	CLCD

·Preparation of SMS-Kaolin-Y

	Category	Unit	Value	Database source
Output	SMS-Kaolin-Y	ton	1.00	
Input	Kaolin	ton	0.56	Foreground data
	Sodium hydroxide	ton	0.56	Ecoinvent 3.1
	Synthetic water	ton	0.79	CLCD
	Electricity	kW·h	5.00	CLCD
	Natural gas	Nm^3	67.78	CLCD
	Transport	ton·km	34.50	CLCD

·Preparation of SDA

	Category	Unit	Value	Database source
Output	SDA	ton	1.00	
Input	Sodium silicate	ton	0.16	CLCD
	Sodium aluminate	ton	0.02	Ecoinvent 3.1
	Sodium hydroxide	ton	0.12	Ecoinvent 3.1
	Synthetic water	ton	0.79	CLCD
	Electricity	kW·h	1.20	CLCD
	Transport	ton·km	10.64	CLCD

·Preparation of Y zeolite

	Category	Unit	Value	Database source
Output	Y zeolite	ton	1.00	
Input	T-D	ton	0.75	Foreground data
	SMS-Kaolin-Y	ton	0.61	Foreground data
	SDA	ton	1.29	Foreground data
	Sulfuric acid	ton	0.10	CLCD
	Synthetic water	ton	6.76	CLCD
	Washing water	ton	9.99	CLCD
	Electricity	kW·h	159.96	CLCD
	Natural gas	Nm^3	0.31	CLCD
	Transport	ton·km	3.36	CLCD
Emission	Wastewater	ton	17.75	CLCD

Table S7. Input and output inventories to produce one ton of FeZSM-5 zeolite from chemicals.

	Category	Unit	Value	Database source
Output	FeZSM-5 zeolite	ton	1.00	
Input	Solid silica	ton	1.71	CLCD
	Sodium aluminate	ton	0.14	Ecoinvent 3.1
	Sodium hydroxide	ton	0.33	Ecoinvent 3.1
	TPABr	ton	0.41	CLCD
	Ferrous sulfate	ton	0.08	CLCD
	Synthetic water	ton	9.37	CLCD
	Washing water	ton	10.14	CLCD
	Electricity	kW·h	173.16	CLCD
	Natural gas	Nm^3	10.27	CLCD
	Transport	ton·km	80.91	CLCD
Emission	Wastewater	ton	19.59	CLCD

Table S8. Input and output inventories to produce one ton of FeZSM-5 zeolite from natural minerals.

·Preparation of T-D

	Category	Unit	Value	Database source
Output	T-D	ton	1.00	
Input	Diatomite	ton	1.02	Foreground data
	Natural gas	Nm^3	141.12	CLCD
	Transport	ton·km	48.97	CLCD

·Preparation of SMS-R

	Category	Unit	Value	Database source
Output	SMS-Rectorite	ton	1.00	
Input	Rectorite	ton	0.39	Foreground data
	Sodium hydroxide	ton	0.78	Ecoinvent 3.1
	Synthetic water	ton	0.54	CLCD
	Electricity	kW·h	5.00	CLCD
	Natural gas	Nm^3	47.18	CLCD
	Transport	ton·km	43.32	CLCD

·Preparation of FeZSM-5 zeolite

	Category	Unit	Value	Database source
Output	FeZSM-5 zeolite	ton	1.00	
Input	T-D	ton	1.20	Foreground data
	SMS-Rectorite	ton	0.03	Foreground data
	Sodium hydroxide	ton	0.22	Ecoinvent 3.1
	Seed (ZSM-5 zeolite)	ton	0.14	Foreground data
	Synthetic water	ton	6.71	CLCD
	Washing water	ton	9.92	CLCD
	Electricity	kW·h	145.00	CLCD
	Natural gas	Nm^3	12.62	CLCD
	Transport	ton·km	8.39	CLCD
Emission	Wastewater	ton	16.70	CLCD

Table S9. LCA impact category indicators and uncertainty analysis results of the synthesis of NaA zeolite from chemicals.

	Value	Unit	GWP kg CO_2 eq./kg NaA zeolite	PED MJ/kg NaA zeolite	WU kg/kg NaA zeolite	ADP kg SO_2 eq./kg NaA zeolite	AP kg Sb eq./kg NaA zeolite	EP kg PO_4^{3-} eq./kg NaA zeolite	RI Kg PM2.5 eq./kg NaA zeolite
Sodium silicate	0.44	ton	7.25E-01	1.15E+01	1.30E+01	8.42E-07	4.05E-04	4.20E-04	1.17E-04
Sodium aluminate	0.45	ton	1.47E+00	2.01E+01	7.65E-03	1.03E-04	1.08E-02	2.63E-03	1.77E-03
Sodium hydroxide	0.95	ton	1.28E+00	2.08E+01	9.30E-03	2.03E-05	8.53E-03	3.14E-03	1.79E-03
Water	21.52	ton	4.10E-03	5.40E-02	2.19E+01	3.85E-09	2.16E-05	2.22E-06	6.61E-06
Electricity	181.61	kW·h	1.34E-01	1.89E+00	5.04E-01	8.47E-08	7.10E-04	4.60E-05	2.09E-04
Natural gas	0.22	Nm^3	4.41E-05	6.44E-04	8.66E-05	4.39E-11	2.76E-08	2.53E-09	3.00E-09
Transport	113.78	ton·km	8.34E-03	8.04E-02	6.96E-03	2.83E-08	1.69E-04	3.03E-05	3.19E-05
Wastewater	21.41	ton	2.04E-02	9.25E-02	5.75E-02	2.18E-09	1.24E-05	2.36E-04	1.92E-06
Total			3.64E+00	5.45E+01	3.55E+01	1.24E-04	2.06E-02	6.50E-03	3.95E-03
Uncertainty of result			8.06%	6.39%	16.29%	14.78%	6.91%	7.61%	5.72%

Table S10. LCA impact category indicators and uncertainty analysis results of the synthesis of NaA zeolite from natural minerals.

		Value	Unit	GWP kg CO_2 eq./kg NaA zeolite	PED MJ/kg NaA zeolite	WU kg/kg NaA zeolite	ADP kg SO_2 eq./kg NaA zeolite	AP kg Sb eq./kg NaA zeolite	EP kg PO_4^{3-} eq./kg NaA zeolite	RI Kg PM2.5 eq./kg NaA zeolite
SMS-K	Kaolin	0.70	ton	3.89E-03	5.07E-02	9.73E-03	8.86E-09	4.11E-05	5.79E-06	9.84E-06
	Water	0.99	ton	1.88E-04	2.47E-03	1.00E+00	1.76E-10	9.88E-07	1.02E-07	3.03E-07
	Electricity	7.30	kW·h	5.38E-03	7.59E-02	2.02E-02	3.40E-09	2.85E-05	1.85E-06	8.37E-06
	Sodium hydroxide	1.07	ton	1.43E+00	2.32E+01	1.04E-02	2.27E-05	9.54E-03	3.51E-03	2.00E-03
	Natural gas	85.22	Nm^3	1.72E-02	2.51E-01	3.37E-02	1.71E-08	1.08E-05	9.85E-07	1.17E-06
Water		20.14	ton	3.84E-03	5.05E-02	2.05E+01	3.60E-09	2.02E-05	2.07E-06	6.19E-06
Electricity		158.22	kW·h	1.17E-01	1.65E+00	4.39E-01	7.38E-08	6.18E-04	4.01E-05	1.82E-04
Natural gas		0.14	Nm^3	2.81E-05	4.11E-04	5.53E-05	2.80E-11	1.76E-08	1.61E-09	1.92E-09
Transport		94.90	ton·km	6.94E-03	6.69E-02	5.79E-03	2.36E-08	1.41E-04	2.52E-05	2.66E-05
Wastewater		20.79	ton	1.98E-02	8.99E-02	5.58E-02	2.12E-09	1.20E-05	2.29E-04	1.86E-06
Total				1.61E+00	2.54E+01	2.21E+01	2.28E-05	1.04E-02	3.81E-03	2.23E-03
Uncertainty of result				14.97%	11.86%	23.72%	10.23%	12.08%	13.55%	10.75%

Table S11. LCA impact category indicators and uncertainty analysis results of the synthesis of Y zeolite from chemicals.

		Value	Unit	GWP kg CO_2 eq./kg Y zeolite	PED MJ/kg Y zeolite	WU kg/kg Y zeolite	ADP kg SO_2 eq./kg Y zeolite	AP kg Sb eq./kg Y zeolite	EP kg PO_4^{3-} eq./kg Y zeolite	RI Kg PM2.5 eq./kg Y zeolite
SDA	Sodium silicate	0.21	ton	3.56E-01	5.66E+00	6.36E+00	4.13E-07	1.99E-04	2.07E-04	5.74E-05
	Sodium aluminate	0.03	ton	9.80E-02	1.34E+00	5.11E-04	6.85E-06	7.21E-04	1.76E-04	1.18E-04
	Sodium hydroxide	0.16	ton	2.24E-01	3.62E+00	1.62E-03	3.53E-06	1.49E-03	5.47E-04	3.11E-04
	Water	1.06	ton	1.78E-04	2.34E-03	9.53E-01	1.67E-10	9.36E-07	9.64E-08	2.87E-07
	Electricity	1.61	kW•h	1.18E-03	1.67E-02	4.46E-03	7.49E-10	6.28E-06	4.07E-07	1.85E-06
Sodium silicate		1.13	ton	1.88E+00	2.99E+01	3.36E+01	2.19E-06	1.05E-03	1.09E-03	3.04E-04
Sodium aluminate		0.27	ton	8.83E-01	1.21E+01	4.60E-03	6.17E-05	6.49E-03	1.58E-03	1.06E-03
Sulfuric acid		0.10	ton	5.92E-03	1.96E-01	1.30E-01	3.26E-06	3.16E-05	4.11E-05	7.12E-06
Water		16.22	ton	3.09E-03	4.07E-02	1.65E+01	2.90E-09	1.63E-05	1.67E-06	4.98E-06
Electricity		175.90	kW•h	1.30E-01	1.83E+00	4.89E-01	8.21E-08	6.88E-04	4.46E-05	2.02E-04
Natural gas		0.31	Nm^3	6.28E-05	9.19E-04	1.24E-04	6.27E-11	3.94E-08	3.61E-09	4.28E-09
Transport		78.31	ton•km	5.74E-03	5.53E-02	4.79E-03	1.96E-08	1.16E-04	2.09E-05	2.20E-05
Wastewater		17.25	ton	1.65E-02	7.46E-02	4.63E-02	1.76E-09	9.98E-06	1.90E-04	1.54E-06
Total				3.61E+00	5.48E+01	5.82E+01	7.80E-05	1.08E-02	3.90E-03	2.13E-03
Uncertainty of result				11.84%	9.75%	11.97%	16.74%	7.57%	7.07%	5.54%

Table S12. LCA impact category indicators and uncertainty analysis results of the synthesis of Y zeolite from natural minerals.

		Value	Unit	GWP kg CO_2 eq./kg Y zeolite	PED MJ/kg Y zeolite	WU kg/kg Y zeolite	ADP kg SO_2 eq./kg Y zeolite	AP kg Sb eq./kg Y zeolite	EP kg PO_4^{3-} eq./kg Y zeolite	RI Kg PM2.5 eq./kg Y zeolite
T-D	Diatomite	0.77	ton	4.11E-03	5.36E-02	1.03E-02	9.35E-09	4.35E-05	6.13E-06	1.04E-05
	Natural gas	105.84	Nm^3	2.13E-02	3.12E-01	4.19E-02	2.12E-08	1.34E-05	1.22E-06	1.45E-06
SMS-Kaolin-Y	Kaolin	0.34	ton	1.89E-03	2.46E-02	4.73E-03	4.30E-09	1.99E-05	2.82E-06	4.78E-06
	Water	0.48	ton	9.15E-05	1.20E-03	4.88E-01	8.60E-11	4.80E-07	4.94E-08	1.47E-07
	Electricity	3.05	kW•h	2.25E-03	3.18E-02	8.47E-03	1.42E-09	1.19E-05	7.74E-07	3.50E-06
	Sodium hydroxide	0.34	ton	4.65E-01	7.50E+00	3.37E-03	7.32E-06	3.09E-03	1.13E-03	6.46E-04
	Natural gas	41.35	Nm^3	8.35E-03	1.22E-01	1.64E-02	8.29E-09	5.23E-06	4.79E-07	5.69E-07
SDA	Sodium silicate	0.21	ton	3.43E-01	5.45E+00	6.12E+00	3.98E-07	1.91E-04	1.99E-04	5.53E-05
	Sodium aluminate	0.03	ton	9.47E-02	1.29E+00	4.94E-04	6.62E-06	6.97E-04	1.70E-04	1.14E-04
	Sodium hydroxide	0.15	ton	2.15E-01	3.48E+00	1.56E-03	3.40E-06	1.43E-03	5.26E-04	3.00E-04
	Water	1.02	ton	1.71E-04	2.26E-03	9.18E-01	1.61E-10	9.02E-07	9.28E-08	2.76E-07
	Electricity	1.55	kW•h	1.14E-03	1.61E-02	4.30E-03	7.21E-10	6.04E-06	3.92E-07	1.78E-06
Sulfuric acid		0.10	ton	5.74E-03	1.90E-01	1.26E-01	3.17E-06	3.07E-05	3.99E-05	6.91E-06
Water		16.75	ton	3.19E-03	4.20E-02	1.71E+01	3.00E-09	1.68E-05	1.73E-06	5.14E-06
Electricity		159.96	kW•h	1.18E-01	1.66E+00	4.45E-01	7.46E-08	6.25E-04	4.05E-05	1.84E-04
Natural gas		0.31	Nm^3	6.32E-05	9.24E-04	1.24E-04	6.30E-11	3.96E-08	3.63E-09	4.31E-09
Transport		74.87	ton•km	5.24E-03	5.05E-02	4.37E-03	1.78E-08	1.06E-04	1.90E-05	1.99E-05
Wastewater		17.75	ton	1.69E-02	7.67E-02	4.76E-02	1.81E-09	1.03E-05	1.95E-04	1.59E-06
Total				1.31E+00	2.03E+01	2.53E+01	2.11E-05	6.30E-03	2.33E-03	1.36E-03
Uncertainty of result				12.37%	9.82%	9.78%	23.40%	9.77%	10.37%	9.01%

Table S13. LCA impact category indicators and uncertainty analysis results of the synthesis of FeZSM-5 zeolite from chemicals.

	Value	Unit	GWP kg CO_2 eq./kg FeZSM-5 zeolite	PED MJ/kg FeZSM-5 zeolite	WU kg/kg FeZSM-5 zeolite	ADP kg SO_2 eq./kg FeZSM-5 zeolite	AP kg Sb eq./kg FeZSM-5 zeolite	EP kg PO_4^{3-} eq./kg FeZSM-5 zeolite	RI Kg PM2.5 eq./kg FeZSM-5 zeolite
Solid silica	1.71	ton	7.83E-02	1.99E+00	3.16E+00	3.93E-07	6.26E-05	1.28E-05	2.30E-04
Sodium aluminate	0.14	ton	4.48E-01	6.13E+00	2.34E-03	3.13E-05	3.30E-03	8.04E-04	5.40E-04
Sodium hydroxide	0.33	ton	4.51E-01	7.29E+00	3.27E-03	7.12E-06	3.00E-03	1.10E-03	6.27E-04
TPABr	0.41	ton	1.65E+00	4.14E+01	9.89E+01	1.57E-05	7.98E-03	1.68E-03	1.10E-03
Ferrous sulfate	0.08	ton	4.61E-01	5.59E+00	1.61E+01	4.76E-06	4.42E-03	5.77E-04	9.10E-04
Water	19.51	ton	3.72E-03	4.89E-02	1.99E+01	3.49E-09	1.95E-05	2.01E-06	6.00E-06
Electricity	173.16	kW·h	1.28E-01	1.80E+00	4.81E-01	8.07E-08	6.77E-04	4.39E-05	1.99E-04
Natural gas	10.27	Nm^3	2.07E-03	3.03E-02	4.08E-03	2.07E-09	1.30E-06	1.19E-07	1.41E-07
Transport	80.91	ton·km	5.93E-03	5.72E-02	4.95E-03	2.01E-08	1.20E-04	2.16E-05	2.27E-05
Wastewater	19.59	ton	1.87E-02	8.47E-02	5.26E-02	2.00E-09	1.13E-05	2.16E-04	1.75E-06
Total			3.25E+00	6.44E+01	1.39E+02	5.94E-05	1.96E-02	4.46E-03	3.64E-03
Uncertainty of result			6.49%	7.25%	14.49%	10.38%	4.97%	5.78%	4.70%

Table S14. LCA impact category indicators and uncertainty analysis results of the synthesis of FeZSM-5 zeolite from natural minerals.

		Value	Unit	GWP kg CO_2 eq./kg FeZSM-5 zeolite	PED MJ/kg FeZSM-5 zeolite	WU kg/kg FeZSM-5 zeolite	ADP kg SO_2 eq./kg FeZSM-5 zeolite	AP kg Sb eq./kg FeZSM-5 zeolite	EP kg PO_4^{3-} eq./kg FeZSM-5 zeolite	RI Kg PM2.5 eq./kg FeZSM-5 zeolite
T-D	Diatomite	1.22	ton	6.60E-03	8.61E-02	1.66E-02	1.50E-08	6.98E-05	9.84E-06	1.67E-05
	Natural gas	169.34	Nm^3	3.42E-02	5.01E-01	6.73E-02	3.41E-08	2.15E-05	1.96E-06	2.33E-06
SMS-Rectorite	Rectorite	0.01	ton	6.50E-05	8.46E-04	1.63E-04	1.48E-10	6.86E-07	9.66E-08	1.64E-07
	Water	0.02	ton	3.13E-06	4.12E-05	1.68E-02	2.94E-12	1.65E-08	1.69E-09	5.06E-09
	Electricity	0.15	kW•h	1.11E-04	1.57E-03	4.18E-04	7.01E-11	5.87E-07	3.82E-08	1.73E-07
	Sodium hydroxide	0.02	ton	3.19E-02	5.18E-01	2.31E-04	5.06E-07	2.13E-04	7.80E-05	4.45E-05
	Natural gas	1.42	Nm^3	2.87E-04	4.18E-03	5.63E-04	2.86E-10	1.80E-07	1.64E-08	1.95E-08
Seed		0.14	ton	3.80E-01	8.00E+00	1.67E+01	7.44E-06	2.07E-03	5.28E-04	3.74E-04
Sodium hydroxide		0.22	ton	2.96E-01	4.79E+00	2.15E-03	4.68E-06	1.97E-03	7.24E-04	4.12E-04
Water		16.63	ton	3.17E-03	4.17E-02	1.69E+01	2.98E-09	1.67E-05	1.71E-06	5.11E-06
Electricity		145.00	kW•h	1.07E-01	1.51E+00	4.03E-01	6.76E-08	5.67E-04	3.67E-05	1.67E-04
Natural gas		12.62	Nm^3	2.55E-03	3.73E-02	5.01E-03	2.54E-09	1.60E-06	1.46E-07	1.74E-07
Transport		68.45	ton•km	5.02E-03	4.85E-02	4.18E-03	1.71E-08	1.02E-04	1.82E-05	1.92E-05
Wastewater		16.70	ton	1.59E-02	7.22E-02	4.48E-02	1.70E-09	9.66E-06	1.84E-04	1.50E-06
Total				8.82E-01	1.56E+01	3.42E+01	1.28E-05	5.04E-03	1.58E-03	1.04E-03
Uncertainty of result				8.82%	8.24%	9.33%	19.66%	7.02%	7.60%	6.36%

Table S15. Atom economy calculations of the synthesis of NaA zeolite from chemicals.

Reactant	Molecular weight	Utilized atom	Mass of utilized atom	Unutilized atom	Mass of unutilized atom
SiO_2	60	96 Si, 192 O	5769	-	0
Na_2CO_3	106	96 Na	1104	45 Na, 211 O, 70 C	5251
H_2O	18	-	0	1420 H, 710 O	12780
$Al(OH)_3$	78	96 Al, 192 O	5662	96 O, 288 H	1824
NaOH	40	-	0	96 Na, 96O, 96H	3839
Total			12535		23694

Atom economy=12535/(12535+23694)=34.60%

Table S16. Atom economy calculations of the synthesis of NaA zeolite from natural minerals.

Reactant	Molecular weight	Utilized atom	Mass of utilized atom	Unutilized atom	Mass of unutilized atom
$Al_4Si_4O_{10}(OH)_8$	516	96 Si, 96 Al, 384 O	11431	192 H, 48 O	960
H_2O	18	-	0	96 O, 192 H	1728
NaOH	40	96 Na	2208	384 Na, 480 O, 480 H	16992
Total			13639		19680

Atom economy=13639/(13693+19680)=40.93%