

Supplementary tables

Table S1. Technologies for removing H₂S from biogas.

Topic	Parameter	Physical-Chemical						Biological			
		In-situ precipitation	Adsorption-Fe ₂ O ₃ /Fe(OH) ₃	Adsorption-AC	Membrane separation	Absorption-NaOH/H ₂ O	Biotrickling filter (BTF)	In-situ microaerobic	Bioscrubbers: Thiopaq	Biopuric (Veolia)	Microalgae-based
Influent	Plant size	All	All	All	Small/Medium	Medium/Large	All				
	Max biogas flowrate (m ³ h ⁻¹)	100,000	10,000	900	1400	100,000	1000,000	1,000,000	0.0003-250	2500	1,000,000
	Min biogas flowrate (m ³ h ⁻¹)	0	200	20	0	100	100		50		100
	H ₂ S (ppmv)		0.9–20	0.005–1		1–90	500–10,000		2500–67,000	10,000	1000–15,000
Costs	H ₂ S removal (%)	50–70	99	96	98	98	90	97	99.5	94	100
	CAPEX (€ Nm ⁻³ h ⁻¹)	Very cheap	120–640/Cheap	3–120/Cheap	Very expensive	Expensive	10–41/Medium	10,000–30,000 (€)/Expensive			Medium
	OPEX (€ Nm ⁻³)	0.024/Very expensive	0.021–0.037 Medium	0.0005–0.037 Medium	Expensive	0.03/Expensive	0.013–0.016 Very cheap	0.0018–0.0037 Very cheap			Cheap
Te	Energy consumption (kWh m ⁻³)	Very low	Low	Low	Very high	High	Very low			Low	15/Low

	Space requirements	Compact technique		Compact technique				No additional units needed		
	Demand on chemicals	Yes	Yes	No	No	Yes				
	Problem frequency	High pressure problems				Clogging of column possible	Media clogging			
	Operation simplicity	Low	High	Medium	High	High	Low		Low	Low
	Robustness					High				
Other	CO ₂ removal				Yes	Yes				
	Stage of development	Conventional	Conventional	Conventional				Innovative	Innovative	Lab scale
	Environmental impact	High	High	High	Medium	High	Low	Low		Low

Table S2. Technologies for removing siloxanes from biogas.

Topic	Parameter	Physical-Chemical					Physical (T ^o)	Biological	
		Adsorption-AC	Adsorption-inorganic	Fluidized bed adsorption	Absorption-Organic	Absorption-Strong acids	Membrane separation	Deep chilling (-70-0°C)	Biotrickling filter (BTF)
Influent	Plant size	All	All	Large	Medium/Large	Medium/Large	Small/Medium	Large	All
	Max biogas flowrate (m ³ h ⁻¹)	150,000	150,000	150,000	150,000	150,000	500	150,000	150,000
	Min biogas flowrate (m ³ h ⁻¹)	0	0	1000	500	500	0	1000	0
	Siloxanes removal (%)	50–70	99	96	98	50–70	60	83	40
Costs	CAPEX (€ Nm ⁻³ h ⁻¹)	Medium	Medium	Expensive	Very expensive	Very expensive	Very expensive	Very expensive	Inexpensive
	OPEX (€ Nm ⁻³)	0.003-0.023/ Expensive	Very expensive	Medium	Very expensive	Very expensive	Expensive	Very expensive	Very inexpensive
Te _{net}	Energy consumption (kWh m ⁻³)	Low	Low	High	Very high	Very high	Very high	Very high	Very low

	Problem frequency	High pressure needed and moisture decreases efficiency	High pressure needed and moisture decreases efficiency			Corrosion, environmental issues, hazardous chemicals	Media clogging		
Other	Environmental impact	Medium	High	Medium	Very high	Very high		Medium	Very low
	Stage of development	Conventional	Lab scale	Emergent	Conventional	Lab scale	Emergent	Emergent	Emergent
	Pre-treatment required	Yes	Yes	No	No	No	No	No	No

Table 3. Technologies for removing/converting CO₂ into CH₄.

Topic	Parameter	Physical-Chemical				Physical (T ^o)		Biological		
		Water scrubbing	Solvent scrubbing	Chemical scrubbing (amines)	Pressure swing adsorption (PSA)	Membrane separation	Cryogenic separation	Chemoautotrophic upgrading	Photosynthetic upgrading	In situ desorption
Influent	Max biogas flowrate (m ³ h ⁻¹)	2000	2000	1800	2000	1400	2000			
	Min biogas flowrate (m ³ h ⁻¹)	0	200	600	0	0	20			
	H ₂ S (ppm)	300-2500	Remove before	300	No limit				No	
Effluent	CH ₄ (%)	97	98	99.7	97	97	97	70	90	87
	CO ₂ (%)	2						4		
	H ₂ S (ppm)	Removed			Removed	Removed		No detected		
Costs	CAPEX (€ Nm ⁻³ h ⁻¹)	1800–5500	250–3000	1500–3200	1500–2700	2000–6000	2000–5590		500–2000	
	OPEX (€ Nm ⁻³)	9.1–14	9–13.8	11.2–14.4	9.2–12.8	8.3–13.3	7–25			
Technical	Energy consumption (kWh m ⁻³)	0.2–0.3	0.2–0.4	0.55–0.9	0.23–0.3	0.15–0.76	0.6–1.8	Low	Low	Low
	Space requirements	High	Medium	Medium	Low	Low	Low			

	Demand on chemicals	No	Yes	Yes	No	No	No	Yes	No	Yes
	Problem frequency	Microbial growth, foam		Foam, amine degradation/loss						
	Operation simplicity	High	Low	Low	Low	High	Low			
	Technical availability	95.5	97	93.5	95	96.5				
	CH ₄ losses (%)	1.5	2	0.09	3	0.5	1.9	1	0.9	8
Other	Environmental impact	High	Very high	Medium	Very high	High	Very high	Low	Low	Low
	Stage of development	Conventional	Conventional	Conventional	Conventional	Conventional	Emergent	Lab scale	Lab scale	Lab scale
	Pre-treatment required	Yes	Yes		No	No	No	No	No	