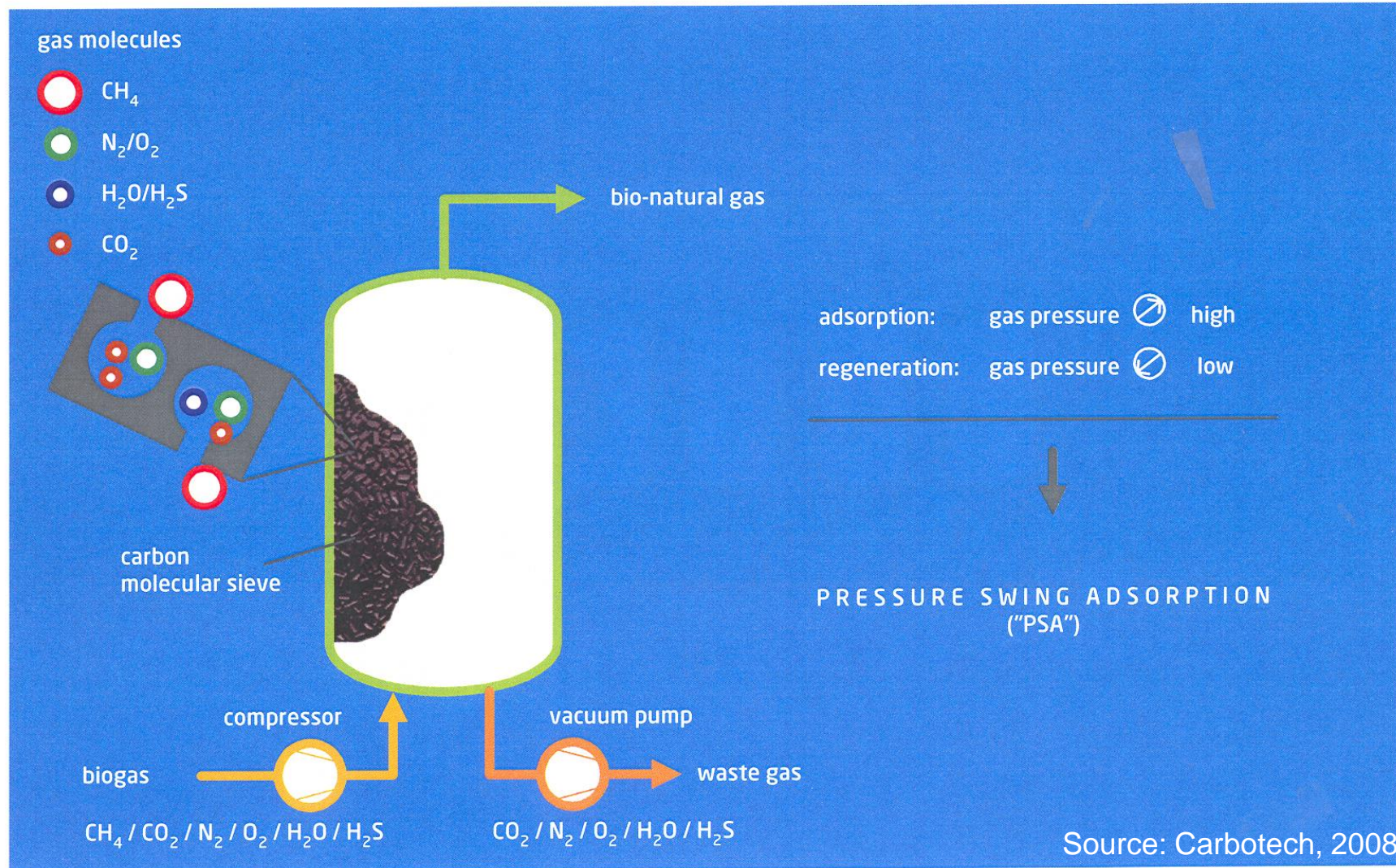


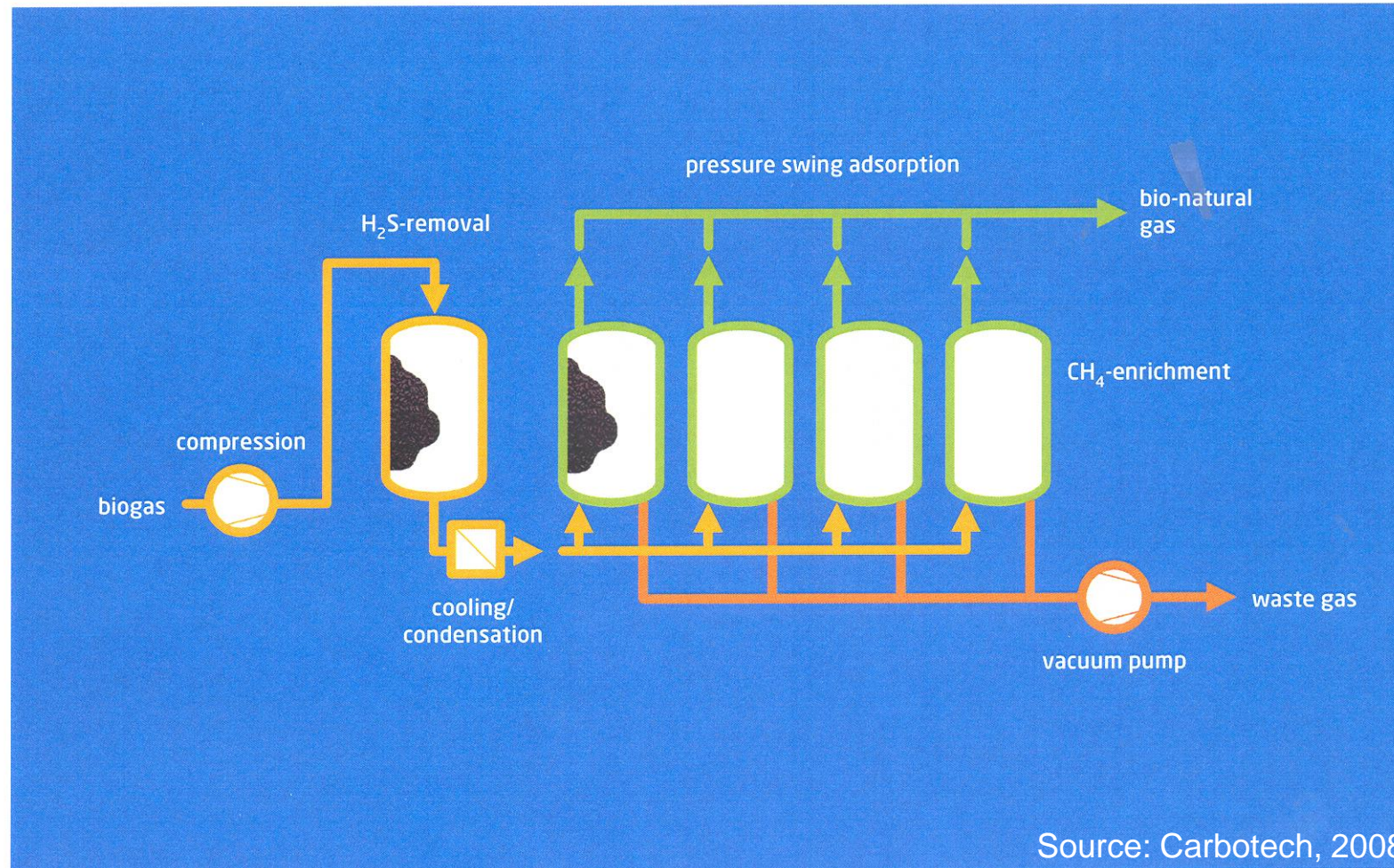
Physical Removal of CO₂: *Pressure Swing Adsorption (PSA)*

- CO₂ is absorbed by adsorption materials (molecular sieve)
- This system is used extensively in Germany and Sweden
- No process water, wastewater treatment, chemicals
- Removal of H₂O to dew point -90°C, N₂, O₂, Hydrocarbon, VOC, and silicon Compounds
- Flexible system, containerized, 97% CH₄ capture

Biogas Clean Up - PSA



Biogas Clean Up - PSA



Biogas Clean Up - PSA

(comminution sewage slurry/organic waste)





PSA Biogas Clean-up; Schandorf, German 71,700 ft³/hr.









Physical Removal of CO₂: *Membrane Filtration*

- Separate due to different permeation rates of a select membrane
 - CO₂ and H₂S is permeate
 - CH₄ is retentate, about 94% pure CH₄
- Typical operating pressure = 235 to 590 psi
- Is an inefficient, high parasitic energy process

Biogas Upgrading Comparisons

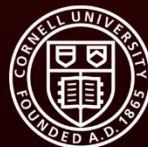
	Water Scrubbing	Amine Scrubbing	PSA	Membrane
Energy consumption kWh/ft ³	0.3	0.67	0.27	N/A
CH ₄ recovery	98.5%	99%	83-99%	90%
H ₂ S co-removal	Yes	Contaminate	Possible	Possible
Liquid H ₂ O co-removal	Yes	Contaminate	Contaminate	No
H ₂ O vapor co-removal	No	Yes	Yes	No
N ₂ and O ₂ co-removal	No	No	Possible	Partial

Average Cost of Biogas Upgrading

Vendor	Biogas Flow (cfm)	Year	Cost (\$/MMBtu)	Technology
Metener	118	2006	6.22	Water Wash
Molecular Gate	142	2008	7.08	PSA
Carbotech	148	2008	10.73	PSA
QuestAir 1 Stage	142	2008	6.73	RPSA
QuestAir 2 Stages	142	2008	7.54	RPSA

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