# Scale up of Hollow Fibre Membranes for Biogas Upgrading

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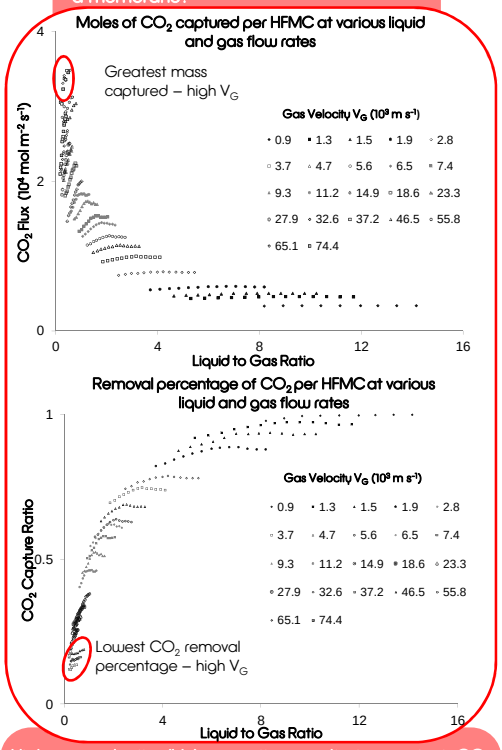
**Stream**
The Industrial Doctorate Centre for the Water Sector

Hollow fibre membrane contactors (HFMCs) can intensify processing of biogas at a wastewater treatment works (WwTW), and allow contact between ammonia rich liquors and biogas. Ammonia and $CO_2$ react, increasing $CO_2$ flux. A crystalline reaction product, ammonium bicarbonate, is grown to recover ammonia as a fertiliser. The process could lead to a potential 500% net increase in revenue. Investigation of scale up equations and process design based on experimental data will facilitate an economic design analysis of the process.

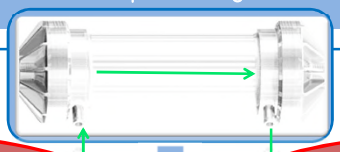
**2014 Project Start**

**What's the most effective way to operate a membrane?**




High gas velocity ($V_G$) operation results in greatest $CO_2$ mass captured but the lowest $CO_2$ removal percentage. In terms of $CO_2$ flow (mL min$^{-1}$), 99% capture of 50mL would be 49.5mL but a 10% capture of 2000mL would be 200mL, a marked increase. A module operated at high $V_G$ can remove up to 10 times more $CO_2$, increasing efficiency in terms of $CO_2$ captured per m$^2$ of membrane. However, to reach a total 99% removal percentage, additional modules to treat the reaming $CO_2$ in the gas flow (modules in series) would be needed. If operated at low $V_G$ multiple in parallell modules would be needed e.g. 40 x 50mL min$^{-1}$ modules for a 2000mL min$^{-1}$ gas flow.

**0.5m² module analysis. Lab design. Shell side gas**

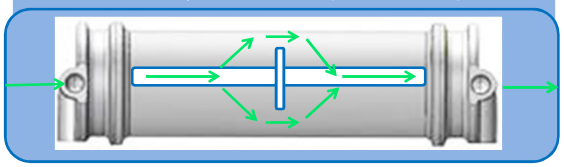


Challenge — Biogas — Biomethane — Challenge

1 Example Data — Outcome

Example Data 2 — Outcome

**1.4 m² module analysis. Industrial design. Lumen side gas**



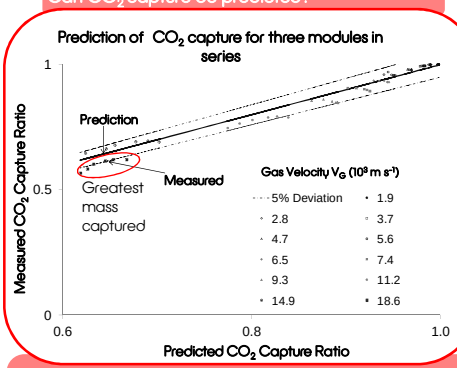
**Future Challenges**

- What is the impact of real return liquors?
- What is the impact of real biogas?
- What is membrane lifetime?
- How does it compare to water wash columns?

Challenge — Example Data 3 — Outcome

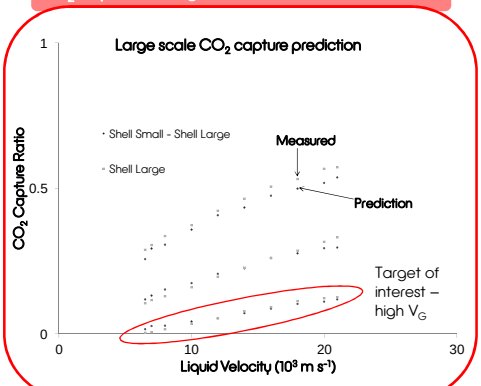
**Pilot scale demonstration at a WwTW**

**Are multiple modules in series more efficient? Can $CO_2$ capture be predicted?**




Modules in series offer increased $CO_2$ capture over single modules and are predictable. Modules in series require 30% less surface area to reach 99% $CO_2$ removal of a large gas flow than modules in parallel. Module number, gas and liquid velocity to reach 99% removal can be predicted, the basis for an economic design analysis

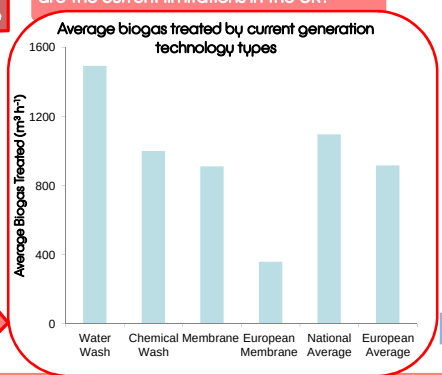
**Can data from small modules be used to predict $CO_2$ capture in large modules?**




Predictions appear valid with identical liquid dispersion. Industrial scale may be predictable from lab experiments

**Biomethane market assessment. What are the current limitations in the UK?**

Challenge — 4 Example Data — Outcome




61 sites commissioned since 2012. A fast growing market

**Can HFMCs be cost effective in upgrading biogas to biomethane at a WwTW? Economic design analysis as ultimate outcome.**

**2018 Project Completion**

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