Work-Package 2.1.1 "Air Capture of Gasses from housing facilities" [1]

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A feasibility study is underway for the Dutch Ministry of Agriculture on the prospect of capturing and filtering both ammonia and methane from barn air. In particular, the challenge is to extract barn air, possibly targeted at feed fence or cow end in cubicle, with sufficiently high concentration of methane to be oxidized in, for example, a biobed.

Introduction

Research aimed at reducing methane emissions in dairy farming has focused primarily on reducing methane formation in the forestomachs through breeding, the use of methane-inhibiting additives and methane-reducing feeding strategies. The alternative by capturing and oxidizing air in barns has been relatively little studied. In dairy barns, the main obstacle is the combination of a relatively low methane concentration and the associated flow of ventilation air. With exceptions, reported methane concentrations are in the range of 5-50 ppmv, with ventilation flows of at least 500 m3 air/cow/hour. Biofilters relying on methane oxidation by methanotrophic microrganisms and chemical-physical approaches using combinations of adorbents and catalysts are capable of capturing and oxidizing methane, as has been demonstrated in laboratory and pilot experiments. Application of these techniques to the ventilation air of current dairy barns would require unrealistically large and expensive installations. Treatment is estimated to require minimum methane concentrations on the order of 300-2000 ppmv combined with advanced treatment technology (Galama et al, in prep. 2023).

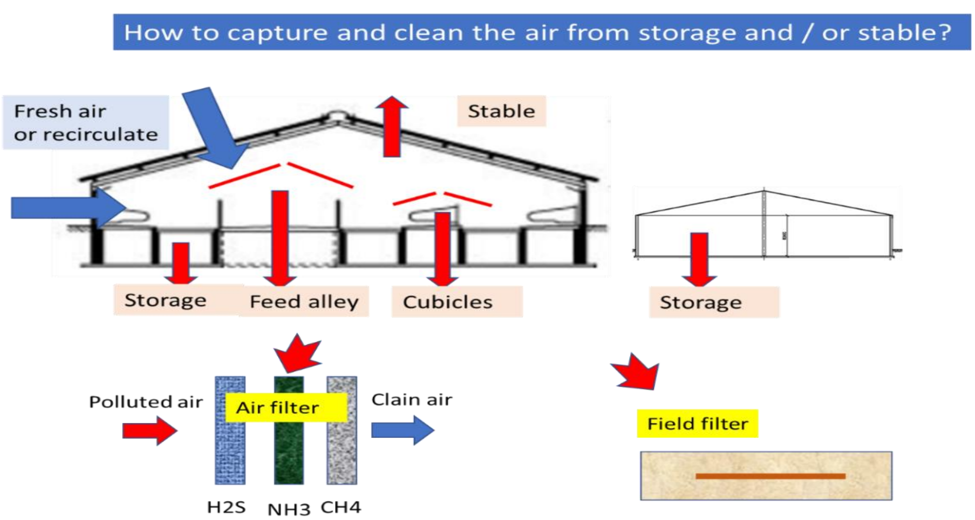

Figure 1. Diagram of air capture

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Feasibility study

A feasibility study (Galama et al, in prep., 2023) examined options for creating air streams with elevated methane levels. Recirculation of barn ventilation air to concentrate methane will also concentrate other gases, including carbon dioxide, ammonia, hydrogen sulfide and moisture, which can harm animal health directly or by causing heat stress. Recirculation would thus require additional technology to remove these gases and additionally remove dust. Another option is to capture methane with a box modification used for experimental assessment of methane emissions by individual cows (see Figure 2). The modification could take the form of a hood over the box and possibly other areas where the cows spend extended periods. Preliminary calculations indicate that up to 70% of the methane exhaled by the animal could be captured in a cubicle with concentrations of approximately 200 ppmv.

Figure 2. Measuring methane concentrations in methane box at cow end of cubicle (Left Netherlands, right Denmark)

Experiment France

(data and figure delivered by Nadege Edouard and Paul Robin from INRAE PEGASE, France)

Colleagues from the CCCfarming INRAE team (Nadege Edouard and Paul Robin) conducted a short experiment in a pilot barn, as part of the INRAE research station near Rennes. The experiment was conducted in a closed barn with mechanical ventilation. Airflow was controlled by different ratios of fresh air from outside and recirculated barn air. Herein, it was shown that maximum concentrations of 300 ppm of methane are possible, but that CO2 concentrations also increase.

The ventilation flows in the barn unit are shown in Figure 3. There are two independent systems, one for air conditioning with recycling capability and one for return air, i.e., there is a controlled supply of fresh air and an exhaust of old air. There are pipes with fans to let in the air inside the barn building on the left side in Figure 3 and to let out the air outside the barn on the right side in Figure 3. During the trial, there were 3 cows in this barn unit that were fed corn silage and soybean concentrate. If this barn were used under commercial conditions, the number of cows would have been 2 till 3 times larger.

The short test consisted of measuring gas concentrations through different ventilation options. With the available ventilation system, it is not possible to accurately change the ventilation rate. The fans for supplying fresh air or exhausting old air can be turned on/off. The fresh air supplied can be mixed with recycled air from the barn.

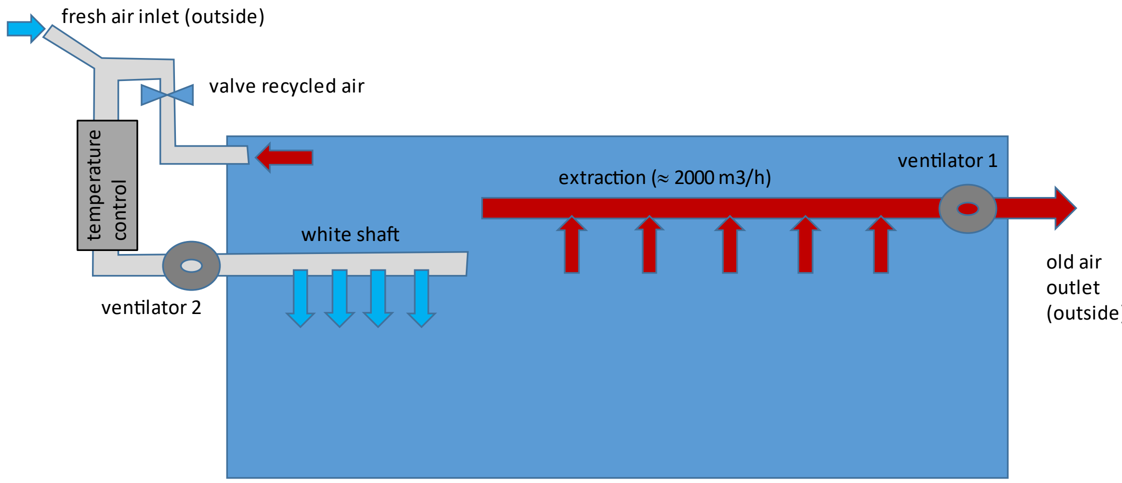

Figure 3. Air circulation diagram of the experimental barn design at experimental farm INRAE (France).

When the extraction was "ON", the concentrations of CO2 and CH4 in the barn unit could not be increased at all. Even when only the air conditioning was "ON" with the recycling option, it was not possible to achieve higher concentrations. Therefore, both systems of air intake and air exhaust were turned off. Subsequently, the concentrations increased. However, the rate of increase decreased after several hours, showing that additional "natural" ventilation was taking place due to leaks from the barn unit (mainly from under the doors and the extraction shaft). In Table 1 concentrations of CO_2 and CH_4 are shown from 0 to 10 hours.

Table 1. baseline data for given periods (total air volume in the barn unit 833m3; ventilation 100m3/hour/cow; simulated concentrations derived from observations).

	Experiment 1		Experiment 2	
Time in hours	CO_2 (ppm)	CH_4 (ppm)	CO_2 (ppm)	CH_4 (ppm)
0	800	30	1100	55
3	3029	136	3146	158
6	4105	187	4133	207
10	4358	199	4365	219

Figure 4 shows the two measurement trials. The measurements of the two trials were taken for about 8 hours. The following hours were simulated (lines with dots). The concentrations that can be achieved with 3 cows are about 4000 ppm CO2 and 200 ppm CH4 and that can theoretically be extended to about 8000 ppm CO2 and 400 ppm CH4 with 6 cows.

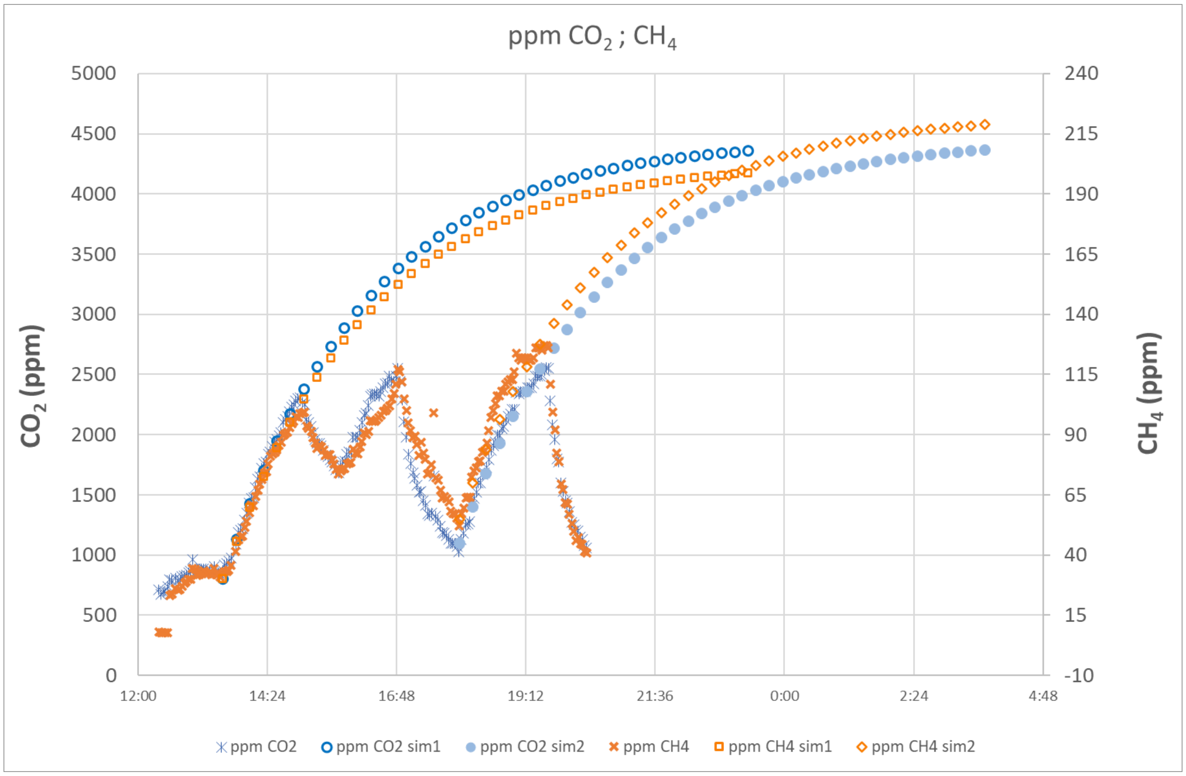

Figure 4. Measured and simulated carbon dioxide and methane concentrations (ppm) in a barn with three cows and reduced ventilation.

It can be concluded that a concentration of methane to a level above 300 ppm should be feasible, in order to test methane reducing technologies in dairy barns. This can be done by reducing the air flow rate to a level of about 50 m3/hour/cow, while the recommendations are between 500 and 1000 m3/hour/cow. As a result, CO2 concentrations, associated gases and airborne particles will also reach high levels that can be detrimental to animal and human health with prolonged exposure.

Further research

To further explore the potential for capturing and oxidizing methane from dairy barns, the feasibility study proposes further research. The focus should be on creating air streams with elevated methane concentrations while ensuring animal health and welfare. Such an air stream should be treated with a biofilter or a combination of adsorbent and catalyst. Both technologies could be further optimized. Biofilters by maintaining optimal conditions in terms of nutrient availability, humidity, porosity and maximization of methane oxidizing capacity. Chemical-physical filters by selecting (combinations) of adsorbents and catalysts and operating temperature. Since reduction of methane emissions from dairy barns may be difficult to achieve in existing farm buildings, redesign of ventilation systems and possibly the farm building as a whole should be part of further research.