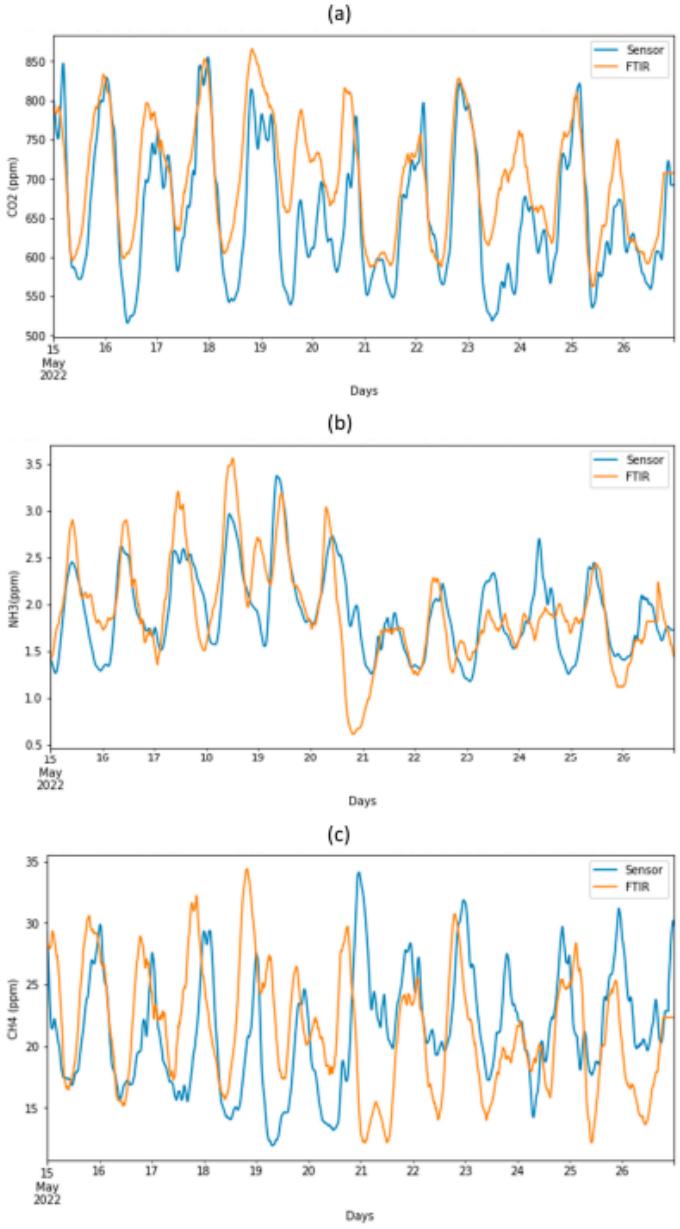
PUREDAE PROJECT DESCRIPTION:

Introduction

Clean and breathable air is a fundamental human right, yet countless individuals and ecosystems worldwide suffer from the detrimental effects of invisible airborne pollutants. Livestock operations significantly contribute to this crisis, accounting for approximately 30% of global methane (CH_4) emissions—a greenhouse gas over 25 times more effective than CO_2 at trapping heat. In addition to methane, livestock also emits considerable amounts of ammonia (NH_3), CO_2, and volatile organic compounds (VOCs), each of which exacerbates climate change and poses serious risks to human and animal health.

In barns, inadequate ventilation and air filtration create hazardous conditions. High pollutant concentrations can cause respiratory illnesses and animal stress, reducing productivity. Additionally, farmers and workers exposed to these emissions are at risk for long-term health issues, including respiratory disorders and chronic diseases.



To find out the average concentration levels over the measurement period in half-opened barns, we went through some research and reached various data, which can be viewed below:

Barn gases mostly include Methane (CH_4), Carbon dioxide (CO_2), and environmental gases like Ammonia (NH_3).

As the graph indicates,

Graph (a) - CO_2
Graph (b) - NH_3
Graph (c) - CH_4

The data ranges;
- Between 562 - 866 ppm for CO_2,
- Between 0.62 - 3.56 ppm for NH_3,
- Between 12.0 - 4.4 ppm for CH_4.

The mean values averaged over the whole period;
- 1.93 ppm for NH_3,
- 21.38 ppm for CH_4,
- 700 ppm for CO_2.

Livestock industries mostly use manure collection methods, which can promote bacterial pathogenesis, as an alternative energy source (e.g., pit systems, biomass). Additionally, these industries often implement ventilation systems to circulate the air and prevent odors and bacterial growth.

We developed "PureDae," an advanced air filtration unit to reduce CH_4, NH_3, CO_2, and VOCs emitted by livestock. It improves air quality, reduces emissions. By improving indoor air quality and converting harmful gases like methane into biogas, PureDae mitigates pollution and transforms it into a valuable energy resource for farmers, paving the way for a cleaner and more sustainable future.

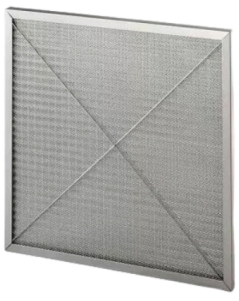
The System

The system operates by extracting air from barns and channels it through a series of filters that capture and neutralize pollutants, including bacteria, volatile organic compounds (VOCs), carbon dioxide (CO_2), and ammonia (NH_3). Following this filtration process, the resulting air will primarily contain oxygen (O_2) and methane (CH_4), separated using a mixed matrix membrane. The O_2 will be released back into the environment, while the methane will be compressed into liquid form and stored within the system. We will discuss the system in four main parts: **Filters**, **Motors**, **Fan**, and **Sensors**.

Filters

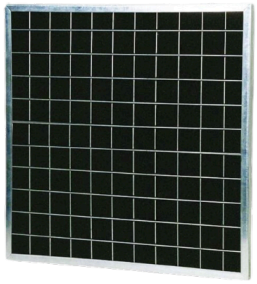
The initial stage of the filtration process starts with a **coarse filter** to capture large particles such as dust and organic debris. This filter reduces the risk of clogging in the subsequent filters and minimizes maintenance requirements. Next, the air passes through a **HEPA 10 filter** designed to remove particles as small as 0.3 microns, including bacteria and viruses. This stage is crucial in livestock environments where microbial contaminants, often released during rumination, pose significant health risks.

An **activated carbon filter** is then used to remove CO_2. The highly porous structure of activated carbon allows for efficient adsorption of CO_2 molecules, helping to mitigate the buildup of this gas in enclosed spaces. To address ammonia (NH_3) emissions, a **phosphoric acid-impregnated activated carbon filter** is incorporated. This filter comprises compressed carbon granules within an outer shell. Following CO_2 removal, the gas stream is less likely to cause chemical interference or saturation of the phosphoric acid-impregnated carbon, thereby maintaining its efficiency and prolonging the filter's lifespan.



Coarse Filter

HEPA 10 Filter



Activated Carbon Filter/ CO2

Phosphoric Ascid Impregnated Activated Carbon Granules

Sensors

Our filtration system will incorporate two distinct types of sensors—pressure probes and methane sensors—to facilitate comprehensive monitoring and optimal operational performance. **Pressure probes** will be utilized for each filtration unit to quantify the filters' pressure differential (ΔP). By systematically tracking ΔP, the users can determine whether the replacement is required for filters and preempting airflow obstructions.

In addition, **methane sensors** will be put at both the inlet and outlet of the system to quantify methane concentrations before and after the filtration process. This configuration will yield calculations of methane reduction efficiency and providing essential data on greenhouse gas mitigation efforts.

Methane Sensor

Pressure Probe/ Sensor

Motors:

To power the airflow mechanisms within the system, **motors** will be employed to ensure consistent air movement throughout the filtration stages. These motors will drive fans to maintain optimal airflow rates, effectively counteracting the resistance introduced by the filters.

Fans:

We will employ two ATEX-certified fans to ensure safe and efficient air circulation within the system. These fans are designed to operate in environments with potentially explosive atmospheres, thereby significantly reducing the risk of ignition due to the presence of methane (CH_4) and other volatile organic compounds (VOCs).

- Initial Fan: Positioned at the upper front of the system, this fan maintains continuous airflow, ensuring the smooth passage of barn air through all filtration stages. Its primary role is to counteract pressure losses across the filters, thereby sustaining optimal airflow rates essential for filtration.

- Methane Collection Fan: The second fan will be located downstream of the filtration system and integrated with the methane separation unit. It will channel the purified methane

gas to storage tanks in liquid form. This fan will maintain sufficient flow to transport methane efficiently while preventing gas buildup.

Fan Flow Rate and ΔP Dependency

The airflow rate (Q) of the fans is directly influenced by the pressure drop (ΔP) across the system's filters and components. The relationship between airflow, pressure, and resistance in the system can be expressed using the fan performance equation, as shown below:

$$Q = \Delta P / R$$

Where:
- Q = volumetric flow rate (m^3/s)
- ΔP = pressure difference across the system (Pa)
- R = system resistance ($Pa \cdot s/m^3$)

As filters become saturated over time, ΔP increases, reducing Q. By monitoring ΔP using pressure probes, the system will dynamically adjust fan speeds via a variable frequency drive (VFD) to maintain constant airflow. This approach ensures sustained performance and energy efficiency.

The required fan capacity can be estimated based on the system's volumetric flow rate and target pollutant reduction efficiency. Assuming:

- A barn airflow requirement of Q_{total} m^3/h
- Filter pressure losses ($\Delta P_{filters}$) of 200–500 Pa
- Piping and system losses (ΔP_{system}) of 100–200 Pa

The total pressure drop (ΔP_{total}) is:

$$\Delta P_{total} = \Delta P_{filters} + \Delta P_{system}$$

The fan's required power (P_{fan}) can then be calculated as:

$$P_{fan} = (Q \times \Delta P) / \eta_{fan}$$

Where:
- η_{fan} = fan efficiency

The ATEX certification ensures that the fans operate safely in methane-rich environments. Additionally, the two-fan configuration provides redundancy, enabling continued operation even if one fan requires maintenance or replacement.

Methane Tank

Once the methane is extracted from the O_2, it should be stored in a tank for potential use as biogas or for direct sale. A metal tank would be an ideal choice for this purpose. The most important factor in selecting the tank is its durability to withstand pressure and the inherent risks associated with the detonability of methane.

Thank you for taking the time to learn about our project. Your interest and support mean a lot to us.

Sincerely,
The PureDae Team