

Multi-criteria optimization of anaerobic digestion processes using artificial intelligence

PhD offer (start at fall 2025)

LBE unit, Narbonne INRAE, France

To apply please send a full curriculum vitae, a cover letter, and reference letters (if any) to jean-philippe.steyer@inrae.fr and remi.servien@inrae.fr. The position is open until filled.

General context

Large language models (LLMs), exemplified for example by GPT-4, have found various applications in fields such as robotics, education and medicine. In the field of robotics, intelligent robots use LLMs to understand their environment, thus facilitating interaction and collaboration with humans (Open X, 2023). LLMs are currently mainly used to control robots. Building on this paradigm, we propose to explore a new application : the use of an LLM to optimize substrate feeding in anaerobic digestion (AD) according to several criteria that are difficult to integrate into a classical approach (i.e., using only mechanistic models). LLM models have several advantages over traditional control methods, warranting further exploration and examination. First, they allow for some explainability : the control algorithm solves the question behind the substrate selections, thus allowing the plant operator to evaluate and actively participate in the decision-making process. This open dialogue between operator and algorithm then facilitates iterative improvement based on mutual understanding and collaboration. It also allows for the use of all knowledge : by leveraging the wealth of information documented in any scientific and technical literature on anaerobic digestion, LLMs can be trained efficiently. As a result, an operator of a single facility is then likely to benefit from a global expertise. For example, Open Source LLMs, exemplified by Llama 2 (Touvron et al., 2023), offer adaptability by allowing local training on new data or access to literature without requiring additional training. Finally, regarding human-machine interaction, one of the main advantages of LLMs is their ability to engage in dialogue with their operators. This dialogue allows operators to dynamically adjust set points, report substrate availability or depletion, request clarification on measurement results, and assess farm stability, which is particularly important for farmers who may not have advanced skills in these complex subjects with diverse and sometimes conflicting purposes. The first results obtained by Gaida (2024) on the subject show that the use of LLMs for this purpose is promising, but that significant work on calibrating and stabilizing the models is still necessary before they can be made usable at an industrial level.

PhD mission and objectives

The objectives of this PhD are of different kinds. The general objective is to demonstrate the usefulness of AI models, more particularly LLMs, as controllers to optimize the anaerobic digestion processes. By using in addition mechanistic models of the material balance type to guarantee a certain robustness to the approach, the LLM will be able to formulate recommendations for the management of the process, for example for the substrate feed, offering transparent and understandable justifications for its decisions. This will ultimately allow the models to be exploited according to a multi-criteria approach (energy, economic and environmental). This overall objective will be divided into different sub-objectives : 1/ a bibliography on the different implementations of LLM models comparing their different advantages and drawbacks, 2/ a methodological comparison on the different tests on the selected models and 3/ finally, an application for the real-time management of methanizers through an implemented algorithm.

Requirements

- We seek a highly motivated fellow for this position. The ideal candidate should possess the following qualifications :
- A master or engineer diploma at the interface between agriculture and data science ;
 - Good knowledge of programming ;
 - Proficiency in the English language ;
 - An interest in environmental problems would be advantageous.

Conditions

Length 3 years.

Location LBE unit, Narbonne INRAE, France.

Gross salary 2100€ including social security.

Scientific advantages Funding to go to different conferences.

Other advantages 45 days of holidays per year, access to the gym and other sporting activities...

Supervision Jean-Philippe Steyer and Rémi Servien.

Contact : jean-philippe.steyer@inrae.fr and remi.servien@inrae.fr.

Funding Half of the PhD funding has already been obtained. Half of the funding is applied for and another application will be made with the applicant.

About INRAE-LBE

The Laboratory of Environmental Biotechnology (LBE) at INRAE is a world-leading research institute dedicated to innovative environmental technologies. We focus on developing sustainable solutions to address pressing global environmental challenges. Our interdisciplinary team of scientists and engineers works collaboratively to advance the field of environmental biotechnology, with a particular emphasis on resource recovery, wastewater treatment, and bioenergy production. More details [here](#).

References

1. Open X-Embodiment Collaboration, Open X-Embodiment : Robotic Learning Datasets and RT-X Models, 2023, <https://doi.org/10.48550/arXiv.2310.08864>.
2. Touvron, H., Martin, L., Stone, K., Albert, P., Almahairi, A., Babaei, Y., and Scialom, T. Llama 2 : Open foundation and fine-tuned chat models, 2023, <https://doi.org/10.48550/arXiv.2307.09288>.
3. Gaida, D. Synergizing language models and biogas plant control : A GPT-4 approach, 2024. In : Proceedings of the 18th IWA World Conference on Anaerobic Digestion, <https://iwa-ad18.org/proceedings-book/>.