

Mass and Energy Balance Report - CCm Technologies low-carbon fertiliser production using algal CO₂ capture

CCUS Innovation 2.0

Key Knowledge Deliverable 4.1

Acknowledgements

We would like to thank Bagley Biogas for collaborating with us on this R&D project and allowing the trial to take place at the Bagley site. We are also grateful to the EA for their guidance, ensuring safe systems of work are in place before operations begin. Lastly, we would like to acknowledge the contribution of all stakeholders towards the success of this project.



© Crown copyright 2026

This publication is licensed under the terms of the Open Government Licence v3.0 except where otherwise stated. To view this licence, visit nationalarchives.gov.uk/doc/open-government-licence/version/3 or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or email: psi@nationalarchives.gsi.gov.uk.

Where we have identified any third-party copyright information you will need to obtain permission from the copyright holders concerned.

Any enquiries regarding this publication should be sent to us at:

nzip@energysecurity.gov.uk

Contents

Introduction	4
Purpose and scope of document	4
Objective	4
Methodology	5
Literature review data	6
References	8
CCm fertiliser production	9
Assumptions	9
Mass and energy balances	9
CCm Bagley algal biomass fertiliser MEB	9

Introduction

Purpose and scope of document

This document details the methodology used to create mass and energy balances (MEBs) for CCm's fertiliser production plant. In the context of the Department of Energy Security and Net Zero (DESNZ) grant project, a fertiliser formulation will be developed using literature review summary data until real-world data can be used to refine the MEB ahead of Perlemax's and Reepel's carbon-rich algal biomass production.

An overview of the process and equipment used will also be highlighted in this report.

Objective

- Explain steps required to create an MEB
- Present data used for fertiliser formulation
- Outline plan to refine MEB with real-world data
- Describe fertiliser production process and plant machinery

Methodology

This section specifies how MEBs are created.

The mass and energy balance contains information about all the material and energy inputs and outputs for the process. In the fertiliser production line, the main criteria required for modelling are:

- Formulation specification, e.g. chemical composition of the product (for example, N-P-K).
- Chemical composition, physical properties and amounts of biogenic materials available (e.g. anaerobic digestion solids) that can be incorporated into the product.
- Ratios of materials that can be used.
- If the process requires a dryer, the amount of energy available on site that can be used, e.g. from a combined heat & power plant (CHP).
- Operating conditions of the plant, i.e. number of hours per day and days per year planned to be running.

In most cases the process can be summarised as follows:

1. Dewatering

Slurries or sludges need to be dewatered mechanically to remove as much water as possible without addition of heat.

2. Stabilisation of biogenic materials

Ammonia and metal oxides in the material are converted to carbonates through reactions with CO_2 .

3. Drying

The stabilised biogenic materials go through a dryer that removes the amount of water required to reach the moisture level range that enables subsequent pelletising.

4. Blending

In order to achieve the desired chemical composition of the product, the dried biogenic material is blended with additives in a mixer according to the proportions required.

5. Pelletising

The blend is fed to a pellet mill that converts the loose material into pellets.

The MEB is modelled to establish a least-cost formulation that achieves all the product specifications, whilst keeping within the process parameters established by the initial assumptions.

Literature review data

This section contains a summary of reference algal biomass data used for MEB modelling.

Composition of biofertilisers as a product of microalgal treatment can vary significantly depending on the feedstocks and algal species. Table 1 shows the different ratios of nitrogen, phosphorus and potassium (N-P-K) in biomass from microalgae-based systems and reference biofertilisers (compost and pig manure) for comparison.

Table 1: N-P-K ratios in different fertilisers [1]

Fertiliser	Feedstock	N-P-K ratios (diluted)
Microalgal biomass	Municipal wastewater	1-0.21-0.12
Microalgal biomass	Municipal wastewater	1-0.20-0.47
		1-0.12-0.36
Microalgal biomass	Municipal wastewater	1-0.17-0.08
Microalgal biomass	Meat processing industry wastewater	1-0.21-0.03
Compost containing grasses, stubbles, plant leaves and farm manure (cattle)	-	1-0.23-0.89
		1-0.46-0.38
Pig manure	-	1-0.64-0.62

On average, studies describe an N:P ratio of 5:1 with distinct proportions of K, but this will vary depending on the species and nutrient availability. Álvarez-González et al. (2022) reported the following microalgal biomass composition using municipal wastewater: 12% dry weight of 7.6% N, 1.6% P and 0.9% K [1].

Castro et al. (2019) reported the following dry weight algal biomass composition using meat processing industry wastewater: 5.6% N, 1.2% P and 0.1% K [2].

Table 2 shows the full chemical characterisation of dried algal biomass.

Table 2. Chemical characterisation of dried algal biomass [2]

N	P	K	C	H	O	Ca	Mg	S	Na
(%)									
5.6	1.2	0.1	38.4	6.5	28.6	9.8	0.4	1.0	0.8
Zn	Fe	Mn	Cu	B	Cd	Pb	Cr	Ni	
(ppm)									
193	23,415	158	37	2.9	ND	ND	23.2	15.1	

ND = Not detectable.

Sharma and Khan (2013) reported the following dry weight algal biomass using municipal wastewater: 2.2 to 3.5% N, 0.3 to 1% P and 0.3% K [3].

Sharma et al. (2021) reported the following dry algal biomass using municipal wastewater: 6% N, 1% P and 0.5% K [4].

There would be a higher amount of N for the chemically derived/recovered solid precipitate. This is therefore expected to reduce ratio in the biological component slightly.

References

- [1] Álvarez-González, A., Uggeti, E., Serrano, L., Gorchs, G., Ferrer, I., Díez-Montero, R., 2022. Can microalgae grown in wastewater reduce the use of inorganic fertilizers? *Journal of Environmental Management*, Volume 323, n. 116224, 2022, <https://doi.org/10.1016/j.jenvman.2022.116224>.
- [2] Castro, J. S., Calijuri, M. L., Mattiello, E. M., Ribeiro, V. J., Assemany, P. P., 2019. Algal biomass from wastewater: soil phosphorus bioavailability and plants productivity. *Science of The Total Environment*, Volume 711, n. 135088, 2020, <https://doi.org/10.1016/j.scitotenv.2019.135088>.
- [3] Sharma, G. K., Khan, S. A., 2013. Bioremediation of Sewage Wastewater Using Selective Algae for Manure Production. *International Journal of Environmental Engineering and Management*, Volume 4, n. 6, 2013, https://www.ripublication.com/ijeem_spl/ijeemv4n6_10.pdf.
- [4] Sharma, G. K., Khan, S. A., Shrivastava, M., Bhattacharyya, R., Sharma, A., Gupta, D. K., Kishore, P., Gupta, N., 2021. Circular economy fertilization: Phycoremediated algal biomass as biofertilizers for sustainable crop production. *Journal of Environmental Management*, Volume 287, n. 112295, 2021, <https://doi.org/10.1016/j.jenvman.2021.112295>.

CCm fertiliser production

This section explains assumptions used and lists CCm's MEBs for fertiliser production.

Assumptions

For the purpose of developing a reference MEB, it is assumed that the microalgal biomass N-P-K composition will be similar to the literature review data summarised in Section 4. There will be an offset reduction due to nitrogen recovery using the Perlemax process but will be formulated with the biological fertiliser which ought to maintain the ratio.

The mean and median of the dataset is presented in Table 3.

Table 3. Mean and median of reference literature review N-P-K dataset

Reference	Nitrogen (%)	Phosphorus (%)	Potassium (%)
[1]	7.6	1.6	0.9
[2]	5.6	1.2	0.1
[3]	2.2	0.3	0.3
[3]	3.5	1	0.3
[4]	6	1	0.5
Mean	5.0	1.0	0.4
Median	5.6	1.0	0.3

Adopting a more conservative approach, the assumed NPK ratios are 5% N, 1% P and 0.3% K.

For the MEBs, the P and K components henceforth refer to their oxide forms, therefore the target formulation will be a 12:4:5 N-P₂O₅-K₂O fertiliser.

Mass and energy balances

CCm Bagley algal biomass fertiliser MEB

Due to the uncertainty regarding the exact composition and dry weight of the algal biomass, the proposed fertiliser formulation encompasses six scenarios with respect to material handling prior to blending. These scenarios are listed in Table 4.

Table 4. Variations of algal biomass handling for fertiliser MEB

Scenario	Dewatering “dw”	Drying “D”	Mixing with AD solids “AD”
Scenario 1	✓	✓	✓
Scenario 2	✓		✓
Scenario 3	✓	✓	
Scenario 4		✓	✓
Scenario 5			✓
Scenario 6		✓	

Trialling with sample liquors obtained from the Bagley Biogas anaerobic digestion plant will help fine-tune the fertiliser formulation with a more representative dataset and help determine which scenario yields the best pellets in terms of consistency and nutrient content. A more accurate MEB will also enhance the cost-effectiveness of CCm’s bio-formulated low-carbon fertiliser by using the optimal quantity of feedstocks/additives for the desired formulation.

If you need a version of this document in a more accessible format, please email alt.formats@energysecurity.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.