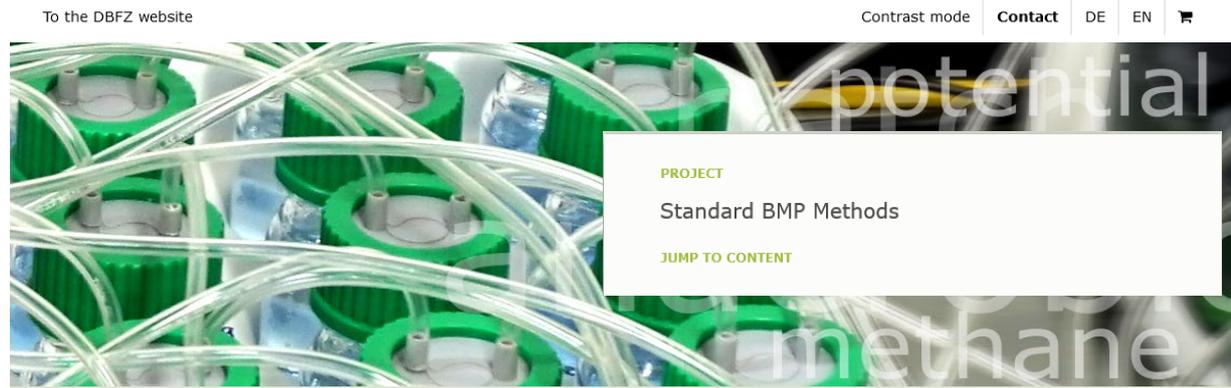




Final Report

# Dissemination of the results of the international inter-laboratory studies of BMP tests



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## Standard BMP Methods

Accurate measurement of biochemical methane potential (BMP) is essential for biogas research and practice. This site provides information and documents (mostly free and open-access) aimed at standardizing BMP measurement.

To get started with accurate BMP measurement, select [Methods](#). If you are new to BMP, start with [Basics](#).



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## Zusammenfassung

Nach zwei Ringversuchen, in denen neue Anforderungen und Validierungskriterien für BMP-Messungen definiert wurden, konzentrierten wir unsere Bemühungen auf die Verbreitung dieser Ergebnisse. Innerhalb der Internetseite des DBFZ, dem Deutschen Zentrum für Biomasseforschung, wurde eine neue Internetseite mit dem Titel „Standard-BMP-Methods“ erstellt. Diese Internetseite bietet verschiedene Open-Access-Dokumente in mehreren Sprachen an, die es ermöglichen zu lernen, wie man BMPs genau misst, aber auch, wie die erhaltenen Daten verarbeitet werden und ein BMP-Test angesetzt wird. Darüber hinaus wurden die neuen Anforderungen und Validierungskriterien im einem Water Science & Technology Paper veröffentlicht und der IWA-Fachgruppe Anaerobe Vergärung sowie auf verschiedenen Konferenzen und Workshops für Wissenschaftler und beratende Ingenieure vorgestellt. Schließlich wurde OBA, die Online-Biogas-App, verbessert und um ein BMP-Testplanungstool erweitert.

## Résumé

Après deux études inter-laboratoires où de nouvelles exigences et critères de validation pour les mesures de BMP ont été définis, nous avons concentré nos efforts dans la diffusion de ces résultats. Un nouveau site web intitulé « Standard BMP methods » a été créé au sein du site web du DBFZ, le centre allemand de recherche sur la biomasse. Ce site web propose différents documents en libre accès en plusieurs langues permettant d'apprendre à mesurer avec précision les BMP mais aussi comment traiter les données obtenues et comment mettre en place un test BMP. En outre, les nouvelles exigences et critères de validation ont été publiés dans un article de Water Science & Technology et présentés au groupe de spécialistes IWA Anaerobic Digestion ainsi que lors de différentes conférences et ateliers pour les scientifiques et les ingénieurs-conseils. Enfin, OBA, l'application biogaz en ligne, a été améliorée et étendue avec un outil de planification de test BMP.

## Summary

After two inter-laboratory studies where new requirements and validation criteria for BMP measurements have been defined, we concentrated our efforts in the dissemination of these results. A new website entitled "Standard BMP methods" has been created within the website of DBFZ, the German Centre for biomass research. This website offers different open access documents in several languages allowing people to learn how to accurately measure BMPs but also how process the data obtained and how to set up a BMP test. In addition, the new requirements and validation criteria have been published in a Water Science & Technology paper and presented to the IWA Specialist group Anaerobic Digestion as well as at different conferences and workshops for scientists and consulting engineers. Finally, OBA, the online biogas app, has been improved and extended with a BMP test planning tool.



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# 1 Introduction

The biomethane potential (BMP) is a biological test used to determine the amount of methane that can be produced from a certain organic substrate. These tests are used in research and in practice. The different uses of BMPs underline the importance of being capable to determine with high reliability and precision this important parameter of the substrates to be digested. However, different inter-laboratory studies of the past have shown that BMP test results vary considerably between laboratories. During an international workshop in Leysin, Switzerland, in June 2015, the problems with BMP tests have been discussed intensively. Based on these discussions, a paper entitled « Towards a standardization of biomethane potential tests » has been published in *Water Science & Technology* (Holliger et al., 2016), and it has been decided to carry out inter-laboratory studies based on the guidelines published in WS&T.

The first inter-laboratory study has shown that the application of validation criteria as defined in the guidelines considerably decreased the range of BMP test results. On the other hand, the range remained significant despite the application of a standard set of conditions and validation criteria. The obtained results would therefore not make it possible to use the BMP thus measured with the initial objectives to predict the production on an industrial installation from a set of substrates, or to use the BMP as a parameter to validate the proper functioning of an installation. Indeed, the variability in BMP measurements was still much too large.

The second inter-laboratory study was carried out with the goal to define more suitable validation criteria based on quantitative data. Comparing reported BMPs with calculated BMPs from raw data revealed that the calculation is an additional source of variability since many reported BMPs differed from BMPs calculated with one single approach. Using only calculated BMPs, the highest acceptable relative standard deviation (RSD) for cellulose BMP was defined to be 6% which included more than 80% of all tests. It could also be shown that manual manometric and volumetric methane production measurement methods tended to underestimate the gas volume produced. Based on these observations, a new set of validation criteria was defined (RSD cellulose BMP  $\leq 6\%$ , lower and upper limit for cellulose BMP: 340 and 395 mL<sub>CH<sub>4</sub></sub>/g<sub>VS</sub>) and applied. This new validation criteria set decreased the range of substrate BMPs to about 20% and allowed validating 40-50% of the tests. The results obtained during both inter-laboratory studies together with the newly defined validation criteria have been published in an open access article in 2020 (Hafner et al., 2020).

In order to improve the dissemination of the important results that clearly allow considerably increasing the reliability of BMP tests, and most importantly the new requirements and validation criteria, we carried out the project presented in this report.

## 2 Objectives and project organization

### 2.1 Objectives

Already before the start of this project, a group of five researchers that tries since many years to get BMP tests standardized, set up a website entitled "Standard BMP Methods" (<https://www.dbfz.de/en/projects/bmp>) to disseminate the outcome of the inter-laboratory studies and to propose guidelines for the different steps involved in BMP measurement. The five researchers are Sasha Hafner from the Department of Engineering, Aarhus University, Denmark and Hafner Consulting LLC, Reston, Virginia, USA, Sergi Astals from the Department of Chemical Engineering and Analytical Chemistry, University of Barcelona, Spain, Konrad Koch from the Chair of Urban Water Systems Engineering, Technical University of Munich (TUM), Garching, Germany, Sören Weinrich from the Biochemical Conversion Department, DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Leipzig, Germany, and the author of this report.



The website is hosted by DBFZ, a research institute whose objective is application-oriented research and development in the field of energetic and integrated material use of renewable raw materials in the bioeconomy with special consideration of innovative techniques of economic effects and environmental concerns (extract from the shareholders' agreement). This integration of the “Standard BMP Methods” website in a website of a large research institute ensures that the information does not get lost due to missing financial support of our activities.

The objectives of this project were:

1. To complete the “Standard BMP Methods” website with detailed documents on the different BMP measurement methods and add demonstration videos to better illustrate the important steps of these different methods.
2. To improve and complete the OBA web application (<https://biotransformers.shinyapps.io/oba1-dev/>) which is designed to calculate various parameters important in the field of biogas production.
3. To disseminate the information of the newly defined requirements and validation criteria as well as the existence of the “Standard BMP Methods” website by many different channels such as publications, newsletters, and conference presentations.

The expected result of this project was that in the future a BMP measurement protocol, standardized and accepted at international level, will be used on a large scale.

## 2.2 Project organization

The project management was carried out by Sasha Hafner. He called regular online project meetings, wrote meeting minutes, established task lists that were controlled during the next project meeting, and also kept up-to-date a list of deliverables. In order to allow posting comments and propose modifications of the different documents, Google docs have been used.

We had in total five project meetings. The kick-off meeting was held on 30 July 2020 followed by three meetings on 30 September 2020, 27 November 2020, and 4 February 2021. The final meeting was on 6 May 2021. In between these meetings we carried out the different tasks and had regular contact by email to discuss different topics.

# 3 Accomplishments

## 3.1 Complementation of the “Standard BMP Methods” website

Besides improvements in content and layout, we concentrated on providing different documents on the basics of BMP tests, the data processing, and laboratory protocols, as well as easy ways to cite the different documents in publications and reports. Although the main language in science and research is English, we also did efforts to translate the most important documents in different languages.

The main document is entitled “BMP requirements (document 100)”. It includes both required components for any BMP protocol, as well as validation criteria, and it represents the consensus view of more than 50 biogas researchers. To make access to the validation criteria even more easy, we also created a so-called one-pager (document 101). Document 100 is besides in English also available in German, Spanish, French, Italian, and Portuguese. A version in Chinese will follow soon.

In addition to document 100, a document on BMP calculation (document 200) was created that explains in general how BMPs have to be calculated. This basic document on BMP calculations is complemented



with BMP calculation documents specific for the different methods to measure methane production. They include the volumetric, manometric, gravimetric, and gas density methods for methane production measurement.

With regard to laboratory protocol documents, there is at present only the one for the gas density method (document 304) available. Different colleagues that use regularly manual volumetric and manometric methods to measure methane production have agreed to provide specific laboratory protocols for these methods but they are not yet finalized and approved.

Demonstration videos are not yet available which is mainly due to limited access to laboratory facilities during the COVID-19 pandemic.

## 3.2 Improvement of the OBA web application

OBA, the online biogas app, was developed by Sasha Hafner on a volunteer basis to make it easy for anyone to accurately process biogas data and predict biogas production. All calculations are done using the biogas package, an add-on R package for working with biogas data, that has also been developed by Sasha Hafner and his students and collaborators.

During this project, the new validation criteria have been implemented, the nutrition option in the prediction tool has been improved, and some bugs have been fixed. A major improvement of the online biogas app was the addition of a BMP test planning tool. This allows the user to calculate by a standardized procedure how much inoculum and substrate have to be added to the batch bottles. Although normally simple and straightforward, the observed variability in BMP calculation during the second inter-laboratory study led us to conclude that it can only be favorable if as many steps of the BMP test protocols as possible are standardized in order to avoid differences between laboratories.

## 3.3 Dissemination of the information of the newly defined requirements and validation criteria

Although initially not identified as major objective, considerable effort has been invested in the dissemination of the newly defined requirements and validation criteria based on the results of the two inter-laboratory studies. The WS&T paper of 2016 already contained BMP test requirements and validation criteria. This publication has had a high impact with until today more than 10'000 views and 2350 downloads, and being over 260-times cited in another publication. To avoid that people apply the requirements and validation criteria published in the 2016 WS&T paper, we were looking for a solution to link this publication with the results of the two inter-laboratory studies published in 2020. After contacting the editor-in-chief of WS&T, we opted for writing a commentary on the 2016 WS&T paper in the same journal. This allowed to establish a link between the two publications. The commentary was accepted in November 2020 (Holliger et al., 2021) and since then already reached more than 1000 views and 345 downloads.

Another focus of our dissemination strategy was the Specialist Group Anaerobic Digestion of the International Water Association, known as IWA. We submitted a small thematic paper to IWA Connect (<https://iwa-connect.org/message/5f582b027e52b345f46d959c/new-resources-on-standardizing-bmp-measurement>) and also succeeded to get the information included in the last newsletter of this specialist group that was sent out in July 2021 to more than 2200 recipients.

In addition, the results and the new website have been included in presentations at different events. Sergi Astals presented a RedBioLAC seminar: Potencial de Biometanización: metodología básica para procesos anaeróbicos that was an online event in September 2020 for South American Scientists. In the same lines, our work was also presented during the “Jornadas Latinoamericanas en Digestión Anaerobia” that were organized depending on the country in October and November 2020. Sasha Hafner presented



at the International Conference on Monitoring & Process Control of Anaerobic Digestion Processes, an online event organized in March 2021, and Konrad Koch at the Biogasforum Bayern in Spring 2021.

And finally, we created a mailing list with about 200 people to whom we send regular updates on our activities.

## 4 Concluding remarks

The work that was carried out to increase the visibility of the results obtained during the two inter-laboratory studies and to disseminate the newly defined requirements and validation criteria for BMP measurement was most successful and we are very confident that the financial support provided by the Swiss Federal Office for Energy ensured that we are getting closer to a standardized measurement of this very important parameter in anaerobic digestion research and practice. We will continue to improve the website and provide additional documents that are all open access despite the fact that for the moment we lack financial support to continue.

## 5 References

Hafner, S.D., H. Fruteau de Laclos, K. Koch, and C. Holliger. 2020. Improving inter-laboratory reproducibility in measurement of biochemical methane potential (BMP). *Water*, 12(6):1752. doi: 10.3390/w12061752.

Holliger, C., M. Alves, D. Andrade, I. Angelidaki, S. Astals, U. Baier, C. Bougrier, P. Buffière, M. Carballa, V. de Wilde, F. Ebertseder, B. Fernández, E. Ficara, I. Fotidis, J.-C. Frigon, H. Fruteau de Laclos, D. S. M. Ghasimi, G. Hack, M. Hartel, J. Heerenklage, I. Sarvari Horvath, P. Jenicek, K. Koch, J. Krautwald, J. Lizasoain, J. Liu, L. Mosberger, M. Nistor, H. Oechsner, J. V. Oliveira, M. Paterson, A. Pauss, S. Pommier, I. Porqueddu, F. Raposo, T. Ribeiro, F. Rüscher Pfund, S. Strömberg, M. Torrijos, M. van Eekert, J. van Lier, H. Wedwitschka, and I. Wierinck. 2016. Towards a standardization of biomethane potential tests. *Water Science and Technology*, 74(11):2515–2522. doi: 10.2166/wst.2016.336.

Holliger, C., S. Astals, H. Fruteau de Laclos, S. D. Hafner, K. Koch, and S. Weinrich. 2021. Towards a standardization of biomethane potential tests: A commentary. *Water Science and Technology*, 83(1):247–250. doi: 10.2166/wst.2020.569.