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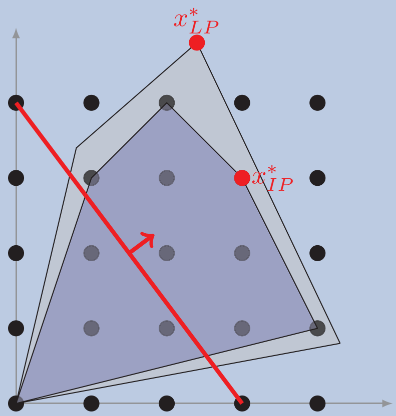



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Application of sensitivity models for renewable resources and co-products

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Abstract

For biomass use one great problem is how to analyse, design and optimize the essential process chains. These process chains show a high level of complexity that leads to several problems. Use of co-products or realisation of cascades increases complexity in addition. For development of new harvesters for new or changed process chains understanding the processes is an important requirement. Combination of technology and process chains actually is not solved for biomass process chains.

For closing this gap, an approach using sensitivity models is presented in this paper. First results show, that sensitivity models are applicable for biomass process chains and product development can be based on this method.

Keywords (required)

Sensitivity-model, biomass, energy supply, self-sufficiency, co-product, harvesting, process chain, compact harvesting

1 Introduction

Cascade use of biomass and bringing more and more co-products into use, could be a worthwhile alternative for today's energy supply. Several research works make demands on this (e.g. Bringezu, 2008, UNEP, 2009). One great problem is how to analyze, design and optimize the essential process chains. The high level of complexity makes high demands on this. Further challenges are existing during practical application of ideas for new biomass usage. For example required harvesters to gain additional biomass as a co-product have to be developed, because actual harvesting technology is not prepared for these additional functions, yet.

In this paper two main aspects of our research work are presented: The integrated approach by use of sensitivity models and the application to an example of a new harvesting technology and process.

2 Problem

The target is, to provide energy for heating, power and mobility, based on an efficient way to use available biomass from co-products. Co-products are organic materials that accumulate while producing agricultural goods. These co-products are not the primary purpose and they are often treated as waste or residual products. If more biomass use from co-products is required, the corresponding process chains have to be understood better. Unfortunately these process chains show a high complexity and there are several external factors with influence on these chains (economics, energy output, sustainability, carbon footprint, sustainability etc.).

Today there is no standard method for modeling and examination of biomass process chains and no agreement about the best procedural method. One reason is the high level of complexity already mentioned, another one is, that several different points of view and expert's opinions have to be respected, each with own requirements. In addition, today's harvesting technology is not prepared for the new task to collect biomass for co-product use while harvesting food and forage. The requirements for new or updated machines have to be derived from the process chains to close technological gaps. In the best case a changing point of view –from a general perspective to get knowledge about relationships along a process chain over relations between market and supplier to specific technological details– should be possible by a proven method.

3 New, integrated approach for biomass supply chains and co-product use

Only building and selling machines is not enough. Also trying to bring new sources for biomass into use is not enough, if the customer's requirements are not respected during development (Beneke et al., 2010). The problem is, that technical aspects, market requirements, realization of process chains etc. have to be respected at the same time. All these different points of view are interconnected. A high number of subjects and a high number of interconnections are a sign of high complexity of a given system.

In a research project, supported by the *Claas Foundation*, sensitivity models have been successfully tested as a new approach for a detailed examination of biomass process chains by the renewable resources research group at UAS Schmalkalden (see Götze, 2012, Brummel, 2012) based on the ideas published in (Beneke et al., 2010). Sensitivity models are known in several tasks, but they are not used for biomass applications, yet. For the first time this method has been adapted to biomass questions. Details of this project are presented in this paper to introduce a new approach for biomass process chains: How to build models for biomass process chains, complexity reduction, multilayer-models for several levels of detail, preparation of scenarios and simulation.

With the example of co-product use in grain production influences on both, harvesters and process chain have been examined, too. The energetic use of chaff and short straw, e.g. as pellets, is possible and the available biomass quantity can be significantly increased. Alternative harvester concepts and necessary changes along the process chains and their consequences are examined in detail. These results together are used in a research project about energy autarkic structures in agriculture. Influences on the process chains and necessary changes are observed, also requirements on possible future combine concepts are shown.

3.1 Sensitivity Models

3.1.1 Method

Sensitivity describes a factor's influence to a system. The system may show reactions as a consequence of the influencing factors. Sensitivity models allow to detect structures or patterns in a system with a high complexity level and provide an opportunity to examine complex systems' behaviour. The target is

- to know the determining factors of a given system,
- to examine, how different factors influence this system (stabilizing, destructive, high or low level of influence etc.),
- to see time dependent effects,
- … .

The problem in complex systems is that the high level of complexity does not allow an approach by reducing the system to its single parts. If this would be done, the connections between the system's parts disappear and a complete description is not possible therefore. Linear correlations are not able to describe the complete system, too. Sensitivity models integrate several levers and connections between the system's parts and simulate the system's behavior altogether. Main flows of mass, energy or information can be represented. The result is a statement about the system's behavior and stability as well as finding adjusting levers for an active system configuration.

Sensitivity models as a scientific method have been developed by *Frederic Vester* in his research group and have been tested out in several applications (see Harrer, 2011, malik management, 2012, Vester, 1990/1995/1997). For easier use of this method a software tool had been developed. This tool is used for the examination of biomass applications by the renewable resources research group at Schmalkalden.

3.1.2 Conclusions for R&D

The research task for the renewable resources research group in Schmalkalden was to examine applicability and potentials of sensitivity models for biomass applications.

Functionality and results from working with sensitivity models allow a detailed examination of complex systems. Biomass applications can be handled and their special properties can be respected in an adequate way. Configuring the system means development and use of technical components (machines), too and gives input for necessary R&D. One additional great advantage is, that design theory in mechanical engineering uses aspects of technical systems and the description of mass, energy and information/signal flows, too (Figure 1). So technical aspects can be derived directly from the sensitivity models and technical aspects can be integrated in the models. This is a new kind of view for technical systems and could not be found in research for biomass applications and technical development before.

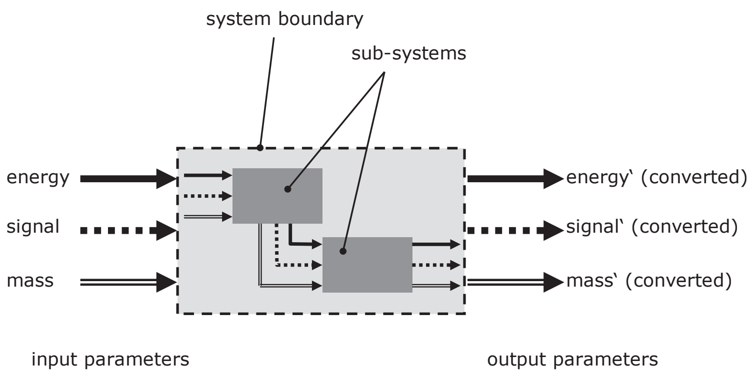

Figure 1: Technical systems, energy, mass and information flows (according to *Pahl/Beitz*)

The symbolic diagram of a technical system in Figure 1 can be used as the basis for sensitivity models for simulation of a system's behavior. Reverse it is possible to find out requirements and basic conditions for technical development tasks by system analysis. For modeling biomass applications, several connected models in several levels of a system have to be built (Figure 2). Every level focuses on own topics. As a result structures and system stability can be examined, dynamic behaviour can be simulated and basic conditions for technical development can be derived (Figure 3).

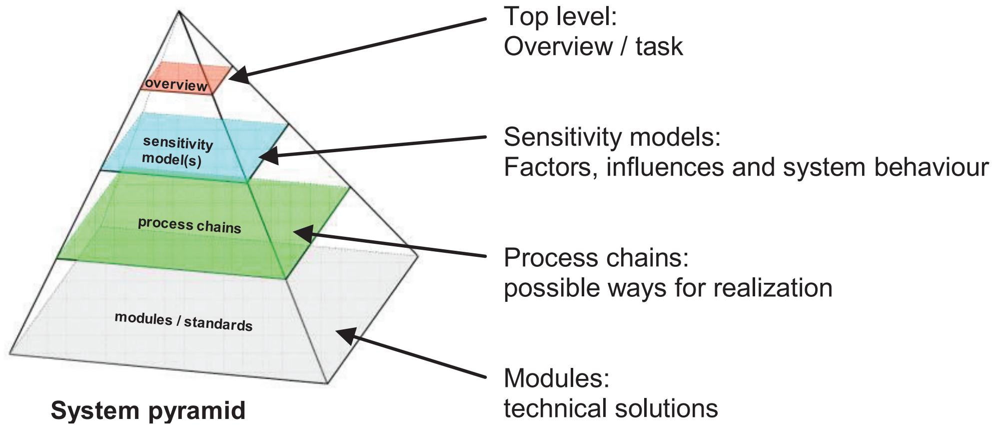

Figure 2: Several levels for sensitivity models in biomass applications and main aspects (source: Brummel & Beneke, 2013)

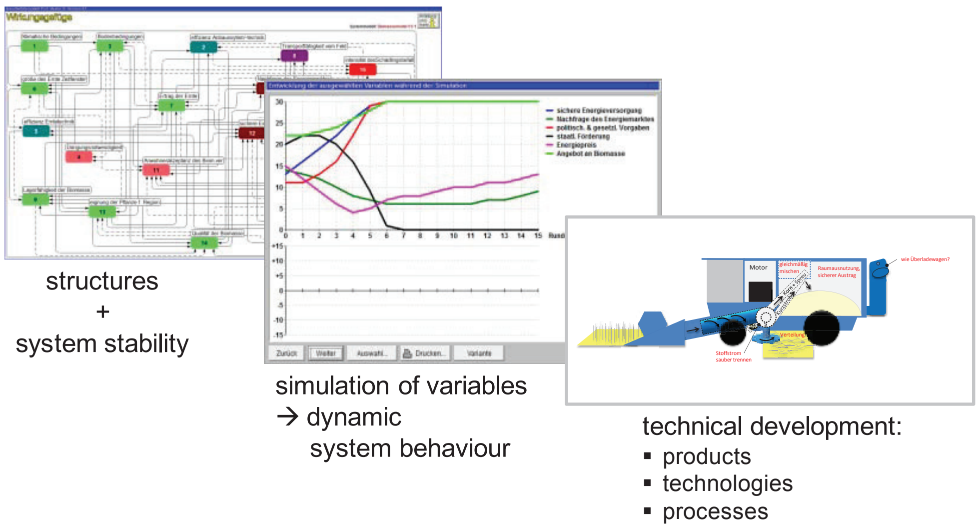

Figure 3: Sensitivity models for biomass applications, different aspects for research

4 Example: Material other than grain to be used as an energy carrier

In former times people collected chaff while they harvested grain and used this additional harvested material for feeding animals. While modern combines offered more and more performance and with reduced customer demand for chaff to use, chaff collecting is not an actual part of grain harvest today.

Material other than grain[1] (MOG) limits the cleaning processes in a modern combine and requires a great part of the combine's power for separation and cleaning processes and spreading this unused material back to the field. Anyway, the old idea of colleting MOG is actual more than ever. Chaff for example offers a biomass resource of 1-2 tons/hectare. This resource actually is still used rarely. For some applications harvesters now had been equipped with a kind of backpack even for collection of MOG as additional biomass. In an additional grain tank these light-weighted materials are collected during threshing. This simple idea of threshing and getting additional biomass at the same time shows great influences on the complete harvesting chains. The processes in today's grain harvest (Figure 4) are enlarged by a wide additional subprocess (Figure 5).

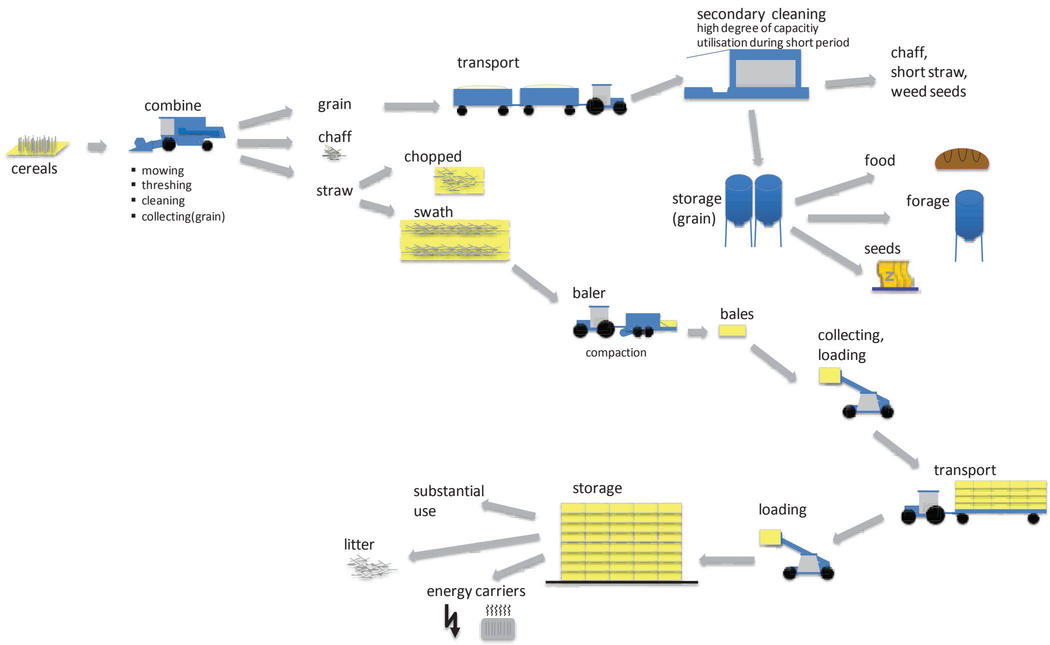

Figure 4: Harvesting chain for grain (straw use included)

This additional sub-process causes additional work, requires transport capacity and deals with problematic, because light-weighted material. Co-products even change the requirements to machines and harvesting processes. In conclusion, just adding a collecting unit to a combine solves the technical problem of biomass collection, but new sub-processes in the harvesting chain appear at the same time and increase complexity.

[1] Material other than grain is a general term in grain production for the biomass that is not grain. The term includes e.g. straw / short straw, chaff or weed seeds.

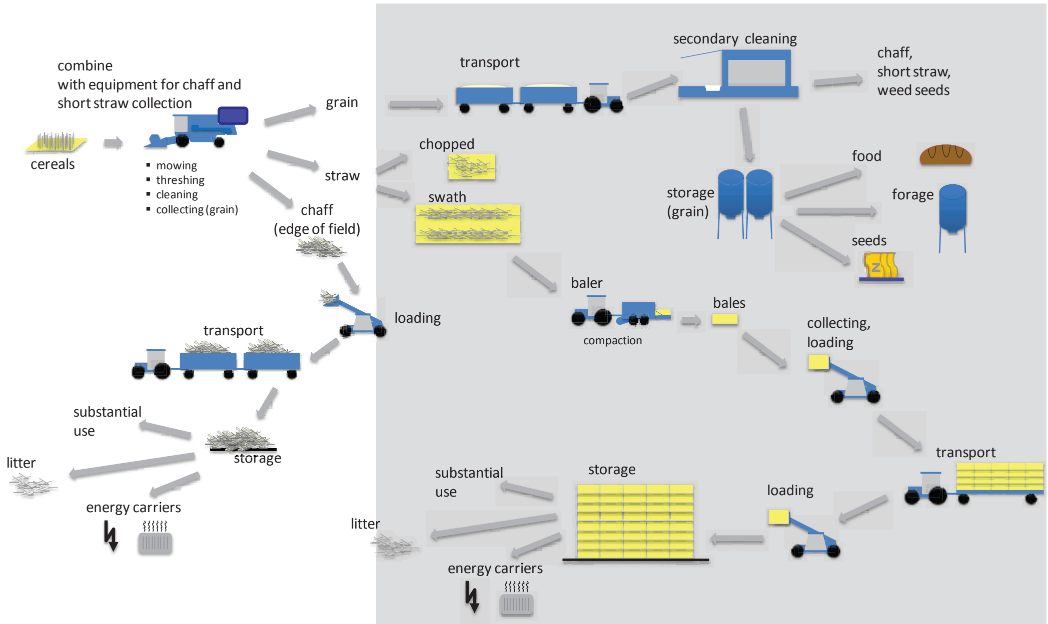

Figure 5: Harvesting chain for grain (straw use included) with additional collection of material other than grain

Notice: the grey box marks the identical parts compared to Figure 4.

After harvesting additional biomass, its storage, conversion and use has to be realized. The very fact, that several possible ways are available for converting biomass into a usable form for energetic use (see Figure 6) shows the high level of complexity in biomass use again.

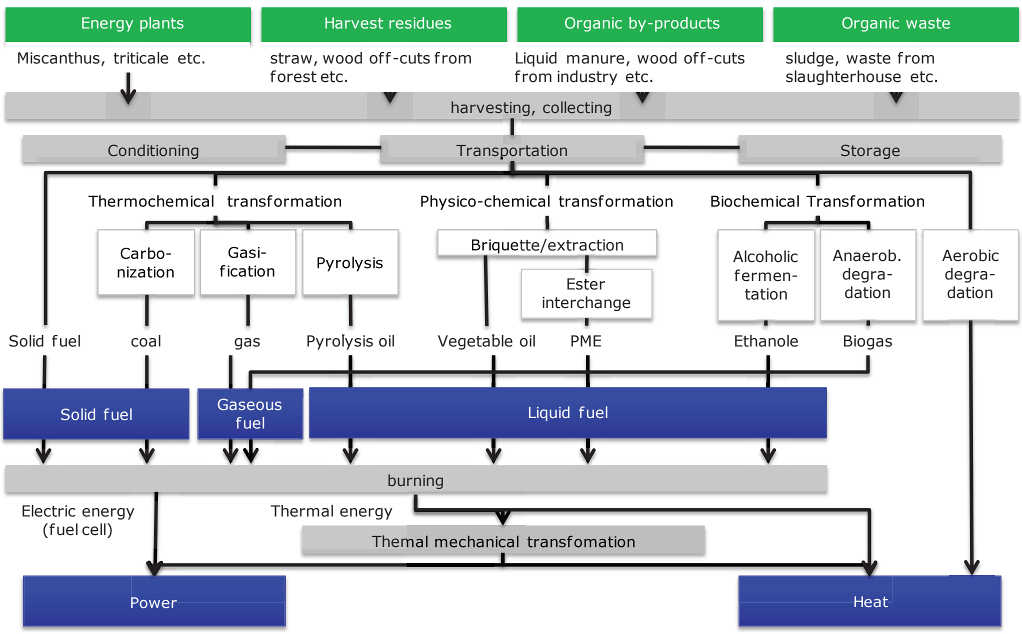

Figure 6: Biomass conversion, overview (according to FNR 2006, translated)

Decisions have to be made for *each* step in the complete process chain for biomass use with respect to possible effects on each other part of the process chain. This shows, that it is impossible to optimize a single step without respect to the changes in the remaining process chain.

Another approach for an integrated view to biomass use from co-products is the compact harvesting. The idea is, to harvest grain and material other than grain at the same time and in a single harvesting process. Straw harvest is included. This requires a new design of the process chain with a changed harvester in the key role. Harvester and harvesting process according to *Rumpler* have been published e.g. in Rumpler, 2010, Rumpler, 2010a, Rumpler, 2011, Rumpler, 2011a. The compact harvesting is shown in Figure 7.

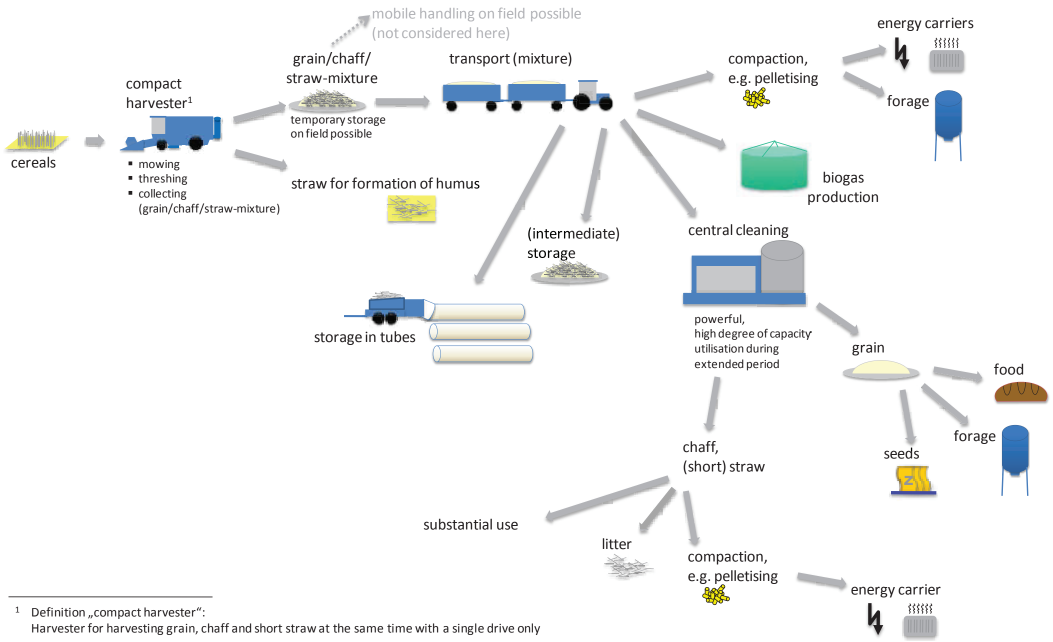

Figure 7: Compact harvesting: harvesting chain for grain, straw and chaff as integrated additional collection of material other than grain

Several different alternative process chains of the compact harvesting have been examined. Actually the layout shown in Figure 7 seems to be the most efficient one. This has been researched in experiments in praxis. A new approach in these experiments has been the use of tubes for storage. This is not a low-budget storage, but offered new potentials by a new technical approach. Further research projects follow up. One aspect is to find out more about the effect of drying in the tube which significantly could influence grain harvest.

5 Conclusions

Sensitivity models are suitable for understanding complex correlations in biomass applications. With this method, new ways for using co-products can be tested before realizing them. Technical development, e.g. harvesters, can be optimized, because there is a much better knowledge of the requirements. With the example of co-products from grain production an economic and sustainable use of additional biomass without conflicts between food and energy, can be shown. A future energy supply, based on biomass from co-products, is actually examined. The target is, to compose new, in parts or complete self-sufficient structures in agriculture. First results are presented as described in chapter 4.

6 Outlook

If additional biomass can be harvested while producing food and forage, the energy contained in this additional biomass could be used for providing energy e.g. to a farm. This is examined in an actual project (see Figure 8) at the renewable resources research group at the University of Applied Sciences in Schmalkalden with project support by the *Claas Foundation*. In several scenarios (farm type, size and structure, geographical position, available co-products etc.) the role and importance of co-products are examined. The target is to find out, if co-products from agricultural processes are able to supply a part of the farm's energy demand. If it is possible, proposals for conversion routes and energy carrier types shall be worked out. One main aspect is the future mobility of farm machines and the source for their energy supply. Necessary machines for closing gaps in future biomass application chains have to be developed.

Sensitivity models are the base for these investigations. Technical proposals for a later realisation of future process chains for energy supply based on biomass shall give technical development new impulses.

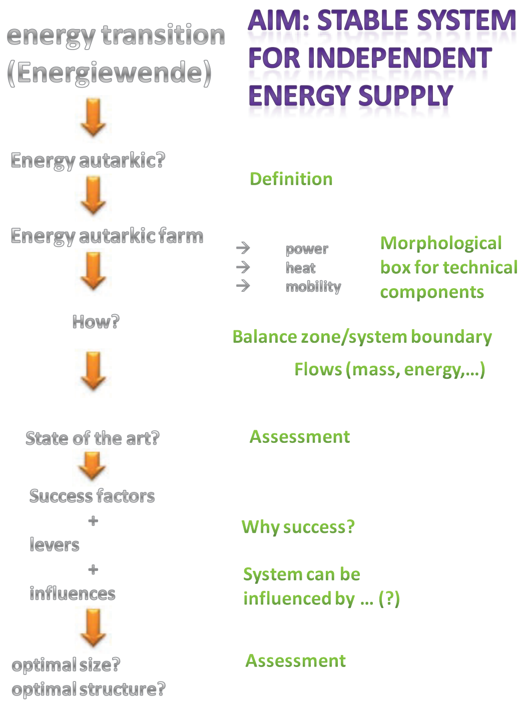

Figure 8: Actual research in use of co-products for energy-supply

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