An Ontology Classifying Residues from the Bioeconomy

Kim Schmidt[1,2,*,†], Kai Sven Radtke[1,†] and Marco Selig[1,2,†]

[1]DBFZ - Deutsches Biomasseforschungszentrum gGmbh, Torgauer Straße 116, 04347 Leipzig, Germany
[2]KIDA, AI consultancy

Abstract

Due to climate change and the Earth overshoot day, that is becoming earlier every year, it is getting more important to use renewable resources and, in particular, biogenic waste and residues instead of fossil resources. There is currently no general scheme to characterise different biogenic wastes and residues and their according legal regulations. We intend to create an ontology that contains all information necessary to (i) clearly identify biomasses and (ii) to enable dealing with it in a bioeconomic and industrial context, which is why the ontology shall be shared with researchers, industry and policy makers. Since this is an early stage work, we want to start with 77 residues from the DBFZ Resource Database developed at the DBFZ Leipzig, Germany.

Keywords

bioeconomy, residues, biomass, ontology, biogenic resources, bio-based products, ecological sustainability

1. Introduction

One of the biggest issues of the 21st century is the climate change. In order to counteract this and lower the world wide CO_2 output, there are many efforts to reuse old products as technical devices and recycle broken items to keep some of the resources in the cycle of economy. Some other approaches are cradle to cradle productions and to lower productions in general. These approaches regarding biogenic resources are part of the bioeconomy that we are focusing on. The term "bioeconomy" in general means "more sustainable business practices in all sectors in which biogenic resources are treated, processed or marketed, including related services, e.g. in the consultancy, trade or restaurant and catering sectors" according to the Federal Ministry of Food and Agriculture [1].

And the affords for sustainable practices are necessary since, according to Lin and Wackernagel [2], the earth overshoot day was on August 1st for 2024 and is continuously becoming earlier each year. For Germany it is even worse, the overshoot day was May 2nd 2024 [3], which is position 35 of 126 countries. The key message of these calculations is, that humanity uses much more resources than the earth can reproduce during one year.

The production of all goods we need and use (primary production, e.g. food, technical devices, energy) and our every day life (e.g. eating, showering) are resulting in a huge amount of waste [4, 5]. However, after certain processing steps, some of these wastes, residues or by-products can be used for other beneficial things. If we use residues wisely instead of just burning or depositing them, some of the primary resources can be replaced and thus their production can be reduced.

To reuse residues, many things have to be considered. Some residues as reclaimed wood or green cutting from the roadside can have a high concentration of heavy metals and thus their recycling is limited. The European Union (EU) passed many guidelines, regulations and laws about how to treat residues [6, 7]. In addition, every country that is part of the EU has its guidelines, regulations and laws about this topic. Hence, it is very challenging to know all of them.

A farmer might wonder, who could be interested in the leafs of their sugar beets or in the liquid manure of their cattle. With more knowledge about the characteristics of their residues and related regulations and laws, producers could make advantageous offers. On the other hand, there might be a

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*Corresponding author.
†These authors contributed equally.
kim.schmidt@dbfz.de (K. Schmidt); kai.sven.radtke@dbfz.de (K. S. Radtke); marco.selig@dbfz.de (M. Selig)

start-up team that is looking for residues to produce more sustainable soles for their new hiking shoes without any clue what could be suitable. Due to the huge amount of different regulations and residues, it is hard for all concerned to get an overview, which residues would be suitable for certain production, how much amount is available, and what is the legal framework. Additionally, there is not yet a central contact point to get this information.

Being aware of so many issues and questions regarding the availability and use of residues, we want to create an ontology that can help different stakeholders to answer their questions. This ontology shall include some of the most applicable guidelines, regulations and laws from EU and Germany for the classification of residues [8]. The different classes of residues will have characteristics that can indicate possibilities for further usage (e.g. amount of available oil or glucose, amount of heavy metals) or funding, and even show current usages.

Until now, this is an early stage work and we are building up a first ontology including only residues from the bioeconomy in Germany. This ontology will include the information from our DBFZ Resource Database (https://datalab.dbfz.de/resdb), which was developed by Naegeli de Torres et al. [9] and contains the yearly amount and some characteristics of 77 biogenic residues. More residues maybe also outside the bioeconomy will follow later. A first inspiration for the ontology was given in Dotzauer et al. [10].

2. Methods and Material

In this section we describe briefly what an ontology is and how we will create our ontology for classifying residues from the bioeconomy. Additionally, we introduce the Resource Database as the base for the first stage of our ontology.

2.1. Ontology

An ontology in the sense of computer science is a formal way to represent knowledge. Domain-specific terms and concepts (called classes) are connected to each other (connections are called relations) and thus portray a part of the real world. An ontology should be machine readable and understandable. This makes them usable for web applications and online search, but also for Artificial Intelligence (AI).

Creating such an ontology is an iterative process and there is never only one correct ontology about on topic [11]. According to Noy and McGuinness [11], the following steps should be considered before starting programming and can be used as a red thread during the genesis of the ontology. However, they can and will be adapted over time.

1. Localize the domain of the ontology and its aim: What is it about and who will use it? What questions shall be answered with the ontology?
2. Reuse existing ontologies: Is there anything suitable already prepared?
3. List necessary terms for classes and relations.
4. Define useful classes and order them in a hierarchy.
5. Define properties of the classes.
6. Define restrictions of the properties (boundaries).
7. Create instances (real world individuals).

Following this recommendation, according to step 1, we defined the bioeconomy as domain of our ontology[1] and everybody offering or requiring residues as target group. The aim is to designate all residues that are available in Germany. The questions, that the ontology shall answer (also called competency questions) are e.g.: How many residues result from the cultivation of leguminous plants? What kind of faeces result from different farming methods of cattle? Can I make bio-plastics from apple pomace? What residue is available for the sole of recyclable hiking shoes?

[1]As already mentioned above, the ontology shall increase over time. We start with a first and small version focusing on the residues from the DBFZ Resource Database. This is what we mean by “our ontology” in the following.

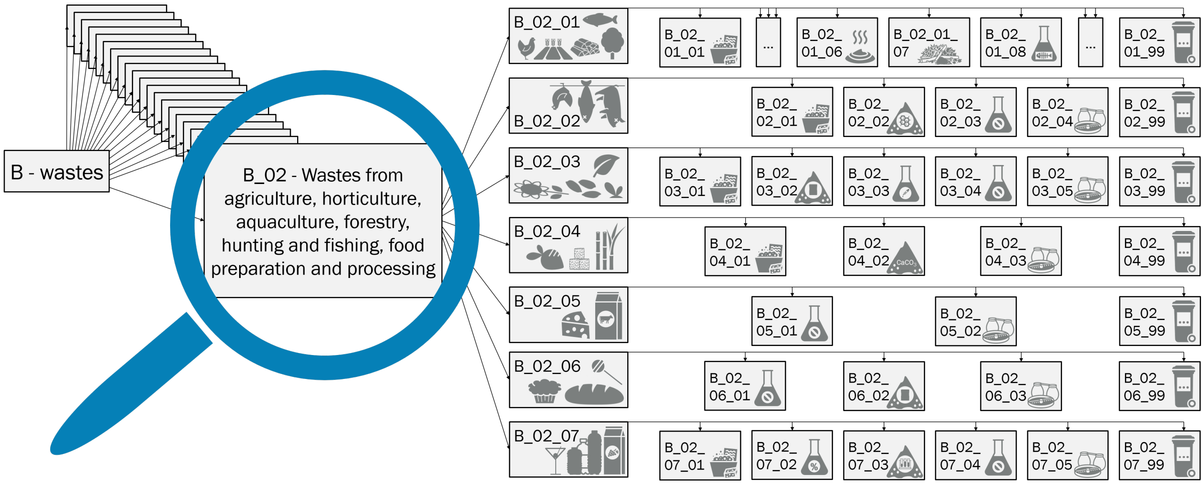

Figure 1: A part of our ontology classifying residues from the bioeconomy programmed in Protégé [15]. The numbers represent the waste codes from the Waste Catalogue Regulation [8]. For better clarity, only a few of these codes are displayed due to their long naming. In the ontology, 20 residue classes are included (*B_01* to *B_20*), where each class has between 1 and 14 residue groups (e.g. *B_01_01*), which again have a number of residue codes (e.g. *B_01_01_01*).
As an example, the residue group *B_02_02* is "wastes from the preparation and processing of meat, fish and other foods of animal origin" with its residue codes *B_02_02_01* "sludges from washing and cleaning", *B_02_02_02* "animal-tissue waste", *B_02_02_03* "materials unsuitable for consumption or processing", *B_02_02_04* "sludges from on-site effluent treatment", and *B_02_02_99* "wastes not otherwise specified". The same symbols in different residue groups have the same meaning.

Following step 2, we found an interesting ontology about bioeconomy called BiOnto [12], which has a broad range of information. Unfortunately it does not offer enough details for our use case, though it is very comprehensive. The BiOnto ontology was not made for a classification of residues, but for an overview of important terms and stakeholders in the topic of the bioeconomy. Maybe some parts of it can be useful in a later stage of our ontology. Instead of using existing ontologies, we focused on regulations as a base, since this is very important for following processing steps of residues. In addition, some questions regarding a taxonomy for residues are already answered with these regulations. The most important regulations are the Waste Catalogue Regulation Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [8] (national implementation of the European Waste Catalogue), the renewable energy directive (RED) II [13], RED III [7], and the DIN EN ISO 17225-1:2021-10 (Solid biofuels) [14].

Some of the necessary terms are e.g. agriculture, forestry, industry, plant-based, animal-based, manure, slurry, leafs, roots, sugar beet, dairy cow, porker, apple pomace, tobacco, reclaimed wood, sludge, biomass, heating value, silicon concentration, etc. The usage of these terms for steps 4 to 6 is still work in progress.

To create the ontology, we use Protégé [15], which is an open source ontology editor from Stanford University. A first glance of the hierarchy is given in Fig. 1. The general design of the ontology can be described as a combination of several taxonomies taken from regulations and guidelines from the EU and Germany, in which a lot of characteristics of residue groups and individuals are included.

2.2. DBFZ Resource Database

The DBFZ Resource Database considers different types of national biomass potentials (e.g., theoretical or technical biomass potential) for Germany. It currently contains information on 77 biogenic wastes and residues [9] for several years. The potentials, possible utilizations and the significance in target markets (e.g. transport sector) can be explored via an interactive web application (see https://datalab.dbfz.de/resdb/potentials). For more information see also Brosowski [16] and Krause et al. [17, 18].

3. Conclusions and Outlook

We want to create a simple way to share information about residues and answer questions about their usage and characteristics. For a high generalization of all this information, we will comply with several national and European regulations and work together with experts from the bioeconomy. Thus we will develop a tool that can be used by farmers, industry but also researchers and policy makers.

As soon as the ontology has reached a stage where enough information is included, we will activate our contacts to different players in the bioeconomy to evaluate our affords and to get more insights, which characteristics are additionally desired. With this already existing network we will bring our work in use later.

In the beginning we will focus on DBFZ Resource Database and its biomasses that are of interest in the bioeconomy. However, we plan to increase the ontology to all residues and renewable resources available in Germany and maybe even Europe. For a more comfortable usage of this ontology we plan to connect it with a Large Language Model (LLM) that answers questions from users directly on the base of the ontology.

LLMs and AI are planned to help maintaining the validity of the ontology. Since regulations keep on changing over the years, this will be an important issue. However, in this stage of the work, in is not the main focus of our activities.

Since this is an early stage work and the ontology is not yet finished, and thus neither well evaluated nor published. However, it is planned to publish the ontology following the FAIR principles.

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