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How to measure the size of a bio-based economy: Evidence from Flanders

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ABSTRACT

The need to shift from a fossil fuel based economy towards a more bio-based economy has received a lot of attention in public debates and policy making in recent years. However, there seems to be some inconsistency in how a bio-based economy is defined as well as how to estimate the size of this bio-based economy. The current article shows, using a Bibliometric analysis, that the topic "bio-based economy" does not come up extensively in the literature by mid 2010. Moreover, it seems that estimating the importance of the whole of a bio-based economy (and thereby not only focusing on one type of production or product) for a region or country is quite rare, besides a few examples. Within Flanders, one such study has been executed by order of the Flemish government. The current article suggests a framework that can be used to estimate the size of the bio-based economy in other regions or countries. It is based on several steps, so called critical points related to conceptualization, disaggregation, information and valuation. The critical points depend on who has and who wants the information, what the context is, what kind of data is available and whether the research should be comparable. The authors suggest that by following their proposed steps, a reliable estimate of the size of the bio-based economy can be calculated.

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1. Introduction

In the last decade a clear shift away from a fossil resource based economy towards a bio-based economy has emerged [1]. In this type of economy, biomass is used as the primary source for producing energy and materials. Stimulating the use of biomass has been a priority for European as well as US governments [2]. However, designing appropriate policy instruments is not an easy task, because the bio-based production chain consists of many different players: primary production including agriculture, processing, distributing, consumption sector and so on. To develop adequate policies, the main actors in the chain need to be identified and it has to be clarified how they interrelate. Moreover, in order to formulate these "adequate policies", it is necessary to have clear baseline and monitoring information of how bio-based the economy currently is [3]. That will enable policy makers and researchers to focus on the most promising parts of the bio-based economy. In the literature, only few studies can be found containing information on the size of the bio-based economy today.

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This article intends to review these existing studies, to identify their shortcomings and to formulate, using an own inventory study in Flanders, a framework that may stimulate other studies of the bio-based economy in different regions.

The article starts with a review of scientific literature on the evolution of the bio-based economy. A following section focuses on a case study in which the authors have tested their suggested method on the case of the Flemish bio-based economy. The last section builds on the case study to discuss the challenges that need to be dealt with in order to answer the question: "how to measure the size of a bio-based economy".

2. Literature review

2.1. *Bibliometric analysis on "bio-based economy"*

First, a bibliometric analysis was performed on articles cited in Web of Science® (WoS) to analyze how important this topic is already in the scientific literature. Using WoS was preferred to using Scopus or Google Scholar based on Meho and Yang [4]. The conference proceedings citation index was not included because the ideas presented in conference papers are often republished in journals at a later stage.

Firstly, the concept "bio-based" as such was examined by entering the following query in WoS: Search for: "bio$based" in "Topic". It was found that this topic was the first time used in 1988, although only once. Since then the number of articles with the topic bio(–)based has increased steadily. In Fig. 1, the three year average frequency is shown of articles with the topic 'bio-based'. This can be compared to the three year average number of articles in the 30% most occurring same journals. The gradually increasing line of articles with the topic bio-based represents an increasing share because the number of articles in the appropriate journals started to stabilize. Mid-2010, a total of 790 articles can be found in WoS with the topic bio-based of which bio(–)based occurred in the title 201 times.

Many of the articles focus on the technological or production aspects of the bio-based technology. 273 articles were found in the subject area of chemistry or biochemistry; 269 on polymer or material science; and 228 on (agricultural) engineering. Another important subarea is the energy and fuels section (with 78 articles). The subject area economy or economics does not occur, meaning that bio-based as such is not linked to economic research or economics in general in the literature on WoS.

Secondly, the concept "bio-based economy" was researched by entering the following query in WoS: search for: "bio$based economy" in "Topic" OR "bio$economy" in "Topic". Articles with these topics are quite rare: only 57 articles occurred in WoS by mid-2010, of which 22 had bio(–)based economy in their title. The first two appeared in 2000, after which we had to wait until 2003 to find another article. Fig. 2 shows the three year average of articles with the topic 'bio-based economy', compared with the evolution in articles with the topic economy. A comparable evolution can be discovered, showing that 'bio-based economy', similar to 'economy', occurs more and more in the literature over the last decade.

Surprisingly, only two of these articles are classified in WoS in the subject area of economics. Most of them belong to chemistry and biotechnology (30), agriculture (13), energy and fuels (10) or engineering (5).

Of course, WoS is not the only place where published research on the bio-based economy can be found, but the short bibliometric study presented above indicates clearly that although many authors have shown an interest in parts of the bio-based concept, few have studied the size of the bio-based economy.

2.2. *Measuring the size of a bio-based economy*

Measuring the size of the bio-based economy can be done in several ways. Firstly, the size of the bio-based economy is related to how much biomass is used as input. Schütte and Peters [5] found that in Germany, about 17% of area of arable land was used in 2008 for the cultivation of renewable resources for material use or to generate energy. Shen *et al.* [6] estimated that about 38% of all biomass used by people in the world is used for the production of bio-based goods and energy, besides food, fibre and feed. Mathews [7] reported in 2009 that about 1% of world agricultural output (unfortunately it remains unclear whether this is in weight, volume or monetary units) is used for biofuels, which is just one part of the bio-based economy.

Secondly, the bio-based economy can be defined by looking at the production side of the economy, the industry. Again several approaches are possible: studying the production processes, determining how well bio-based conversion is

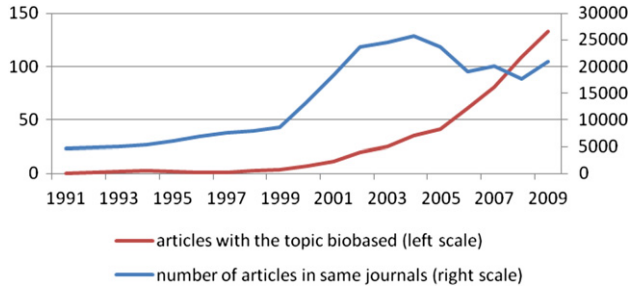

Fig. 1 – Three year averaged number of articles with the topic "bio-based", compared with the total three year averaged number of articles in the same journals.

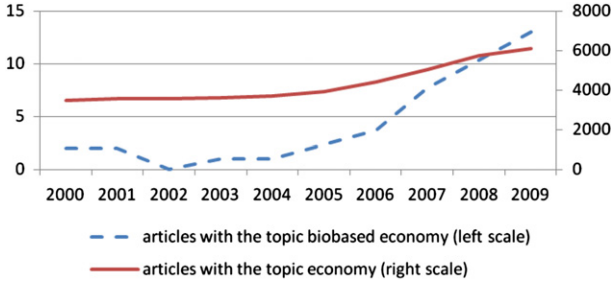

Fig. 2 – Three year averaged number of articles with the topic "bio-based economy" compared with the total three year averaged number of articles with the topic "economy".

integrated in the economy or how many goods are produced in a bio-based way compared with other goods.

An important example is the study of Nowicki *et al*. [8] on the bio-based economy – state of the art assessment. In that study, the size of the bio-based economy in the EU-25 (defined in market value of the final product) was estimated by identifying potential bio-based products. In a second step, these products were further screened to eliminate the products solely used for food or feed and those that will not contain a bio-based component in the future. The rest of the products are considered to be potentially bio-based. Then an estimate was made of the percentage of the production that was actually bio-based in 2005. They found that, within those production sectors where bio-based production is possible, about 54% of the value produced is bio-based in 2005. Based on the current technological developments, the authors believe that this percentage can increase up to 73% of all potential bio-based products. However, this result depends heavily on two important assumptions: 1) a substitution between conventional and bio-based products will only occur when the bio-based products cost less than the conventional products and therefore they need to have a lower market value; and 2) enough biomass needs to be available to substitute the fossil inputs. These two assumptions limit the results of the study, and point exactly to the difficulties encountered when measuring the real value of the bio-based economy.

What is very specific about studies related to the bio-based economy is that most researchers focus on one aspect of production (e.g. biotechnology, biorefinery, biochemistry) or on one type of product (e.g. biofuel, bio-based plastics, biochemicals). For example, Shen *et al*. [6,9] have focused on the topic of *bio- plastics*, and mapped these plastics by contacting the different producing companies and asking them what their production capacity is today and what they expect for the future. Their 2007 estimate was that bio-based plastics had a mass fraction of 0.3% of the worldwide polymers production.

Bio-based energy certainly is that part of the bio-based economy which has been described most extensively [10]. This is not surprising since bio-based energy is economically very important. Since the approximate amount of bio-based energy used in the world economy is about 43–50 EJ [11], with about 8 EJ in industrial societies used at high efficiency and more than 35 EJ used at low efficiency primarily for cooking and heating in developing economies, one can estimate the equivalent value as $8 \times 75\% + 35 \times 15\% = 11.25$ EJ of oil equivalent, or at 100 $ bbl-1 or 16–17 $ GJ-1 = 180 G$ - a sizable amount since the GDP of the world's 47th economy is about that size [12]. Some research on bio-based energy examples of the last year are related to the use of microalgae for bioenergy production [13], the production of biodiesel from soybean oil [14], ethanol from waste products [15], the generation of biogas [16], the use of wood products in co-combustion [17,18] or to the sustainable production of second generation energy crops [19]. Many articles focus on the technical aspects and feasibilities of producing bio-based energy.

One quite different approach to estimate the importance of the bio-based economy is to look at legal limitations and guidelines on the production of bio-based goods. Especially in the case of biofuels, many countries have established well defined quantitative guidelines on the production of biofuels. In Flanders, for example, the energy law requires now that fossil fuels should be blended with 4 vol.% of biofuels. Besides this, there exist also quota limiting the amount of produced biodiesel and bio-based ethanol that can be supported through tax advantages [20]. There might however be a discrepancy between the politically defined targets and actual production and consumption whereby it again becomes difficult to assess actual quantities [21].

Thirdly, the size of the bio-based economy can be estimated by determining what part of consumption is bio-based. Glaser [22], for instance, found that about 8% of the energy consumed in the US was of renewable origin in 2006. Worldwide, 10% of consumed primary energy originated from biomass in 1980 and according to Meeusen [23] this is expected to stay the same until 2030, unless certain technology breakthroughs occur. However, estimating the energy consumed is hindered by the fact that these are secondary and tertiary energy forms such as liquid fuels, electricity and heat for which the statistics get very complicated [24]. Moreover, analyzing the consumption side of other bio-based products is more difficult because certain bio-based products have only recently been put onto the market [25]. Also the fact that especially in developing countries a significant share of bio-based energy may be derived from subsistence production or household waste stream utilization, which by nature are difficult to quantify, will make it hard to give an estimate based on consumption.

As was the case with production, also consumption can be defined by looking at the legal framework. According to energy laws the share (in volume) of biofuels in total transportation fuel consumption has to amount to 10% in 2020 in the EU [26] and 11% in 2022 in the US [27]. To use this information, one would have to wait for a mid-term or ex-post analysis of the policy in order to know whether consumption has reached the presupposed level.

From this short, and certainly not complete literature review it can be seen that each method involves different advantages and disadvantages and leads to different results. Therefore, the authors use a combined approach looking at several steps in the production chain, in order to address the limitations of the available data. For example, if consumption data is missing, data from the production statistics may be used based on reasonable assumptions with respect to conversion and loss factors. The suggested approach has been tested in an inventory study on the bio-based economy in Flanders of which the results are presented below.

3. A case study for Flanders

3.1. *Study area*

Flanders is the Northern part of Belgium (at 50 54 N, 4 32 E) and is, as many other regions in Europe, an economy highly dependent on fossil fuels. For example, the harbor of Antwerp (in the North of the region) has based a large part of its economy on the easy access to fossil fuel and has become very strong in the petrochemical sector [28]. However in the region more to the

West, agriculture is traditionally very strong which might create possibilities for the production of biomass. On the one hand, intensive pig or other livestock production can increase the production of biogas (while dealing with manure surplus) which can be used for the production of heat or electricity. On the other hand, intensive arable, including horticultural, production can provide more biomass residues to be used in various conversion routes of energy production from biomass. It needs to be mentioned though that Flanders relies strongly on the imports of agricultural products, so the potential for building a bio-based economy relying entirely on domestic biomass is rather limited.

Belgium is a federal state in which the regions (besides Flanders, Wallonia and Brussels) can decide on own policies in region specific domains, such as regional economics, agriculture, road infrastructure, spatial planning and environment within the framework established at federal level. Policies related to support biomass production relate mainly to agriculture and is thus a regional competence. In 2010, the Flemish government launched a research project in order to estimate the size of the bio-based economy today [29]. The results are presented on its website and will be used as foundation for new policy actions in the field of bio-based production. At the moment a similar study is being executed in the Walloon region of Belgium, for which the results are expected by the end of 2011 (Jean-Luc Wertz, Valbiom, April 5th 2010).

3.2. Used concept of bio-based economy

The bio-based economy was in the study defined as follows: it is an economy in which the inputs for the production of materials, chemicals and energy originate from biomass instead of fossil (and other non-renewable) resources such as petroleum or hereof derived products. The study delimits the bio-based sector to non-traditional applications of biomass, meaning that the agri-food sector as well as feed production are not incorporated. It is very important to keep this definition in mind, because it means that the results may differ strongly from other research that used a different definition (for example Pellerin and Taylor [3] included food and feed production in their definition). Furthermore, the study focuses on Flemish companies that use biomass coming from professional agri-, horti- and silviculture. Nature care and forest management products are not included. Companies do not need to be completely bio-based to be included. If a company is only partially bio-based, only the bio-based part of the production is taken into account. Bio-based goods is used as a general term, including all kinds of bio-based products and bio-based energy.

3.3. Method

In order to map out the bio-based economy of Flanders, a first step was to define what can be regarded as being part of the bio-based economy. For this purpose, a literature study was performed together with a review of existing studies in neighboring countries. In a second step, the bio-based economy was divided into several sub-categories (see further). For each category a list was made of all companies existing in Flanders. Each company had to have at least one production site in Flanders (in order to exclude pure trading companies). Thirdly, for each subcategory at least one company or federation of companies was selected for an interview. The interviews were mainly used to estimate the part of total production that can be attributed to the bio-based economy. Finally, for each company interviewed as well as for their competitors in the same subsector, data was collected on gross margins and employment using the balance database of the National Bank of Belgium, in order to calculate the relative share of the bio-based economy.

3.4. Results

In the bio-based economy, two sectors were distinguished: the production of energy and of bio-based products.

Bio-based energy means first of all the production of electricity (power) from biomass, be it by way of combustion or any other process. About 1.65% of Flemish electricity production is estimated to be bio-based. A large part of this is produced by burning biomass in combination with fossil fuels, termed co-firing. Secondly, bio-based heat can be produced using a cogeneration system. According to our estimates, about 1.6% of the produced heat in Flanders is bio-based. Thirdly, the production of biofuels in Flanders is investigated. It is not possible to give the production of biofuels as a percentage of total fuel production, because Flanders does not produce fossil fuels. However, it is known that about 4% of the Flemish consumption of transportation fuels consists of bio-based ethanol, biodiesel or biogas, giving an idea of the importance of biofuels compared with fossil fuels. This consumption has been made possible by the quota that have been put on production of biofuels and which has been reached for the first time in 2010. In total, seven companies produce biofuels in Flanders and none of them has reached its full capacity.

Bio-based products are further subdivided into bio-based materials and bio-based chemicals. The most developed form of bio-based materials is based on silvicultural products: fiberboard and paper production. The production based on horti- and agricultural products is today mostly still in a development phase. In Flanders R&D focuses on the production of bio-based rubber and fibers to be used in the automotive, textile and packaging sector. The study of bio-based chemicals appeared to be very difficult, because the production is very diverse and involves many different steps. From general figures for the EU, it was found that about 8% of the chemical production is bio-based. In Flanders the importance of fossil inputs remains very large because the chemical industry has been organized around the fossil fuel availability in Antwerp and a complete shift in production systems would be needed to come to bio-based chemical production. Research and development on bio-based products is quite well developed in Flanders. Especially the chemical sector looks for alternatives for the use of unsecure and exhaustive fossil raw materials. A lot of research is carried out by the industry itself, but also many other research institutes or organizations have programs for research on bio-based products. Policy, however, has until now not focused specifically on bio-based products and much less attention is given to this part of the bio-based economy, compared with the production of bio-based energy.

Based on this inventory, about *1.8 % of the gross margin* of the Flemish economy can be called bio-based, as in using raw material from agri-, horti- and silviculture. The bio-based economy creates *0.4 % of the total employment* in Flanders (see Table 1). Related to employment in industry (secondary sector) only, this amounts to 1.4%. About one fourth of the value added created by the bio-based economy is from the production of bio-based energy: fuels, heat and electricity. In the case of bio-based products (which account for the remaining three quarters of the economic value) about one third of the value is produced by the paper sector, one third by the fiberboard sector and one third by the chemical industry.

4. Discussion

Critical points in the process of estimating the size of a bio-based economy can now be formulated. By providing information on these points, study results for different countries can be compared. Future studies, anywhere, can be guided by the proposed framework (see Fig. 3).

4.1. *Step 1 – Conceptualizing "the bio-based economy"*

A first critical issue is the conceptualization of the term "bio-based economy". The analyses have shown that there is a great difference between how the industry (which possesses the information) defines a bio-based economy, and what scientific literature or policy makers (who want the information) state (see Fig. 3). In theory, a bio-based economy is an economy for which *all* inputs come from renewable resources. Most of the companies interviewed agreed with this definition, although some did not confine the resources only to biomass, but also included, for example, solar or wind energy. Moreover, they enlarged the definition by including items like sustainability, continuity, energy-efficiency, natural or biological products and recycling. However, at the same time none of the companies interviewed believed that an economy can become entirely bio-based: the need for fossil fuels or other non-renewable resources will remain [30]. This discrepancy in definition will be very influential in calculating the size of the bio-based economy. If only completely bio-based companies are incorporated in the definition, the size of the bio-based economy will be considerably smaller than if all companies which make an effort to evolve towards a bio-based production system are included. Therefore, whenever reporting on the results of a study, the used concept of "bio-based" needs to be well explained and described in order to be meaningful.

Table 1 – Biobased economy in Flanders [source: 30].

	Gross margin		Employment	
	x 10^6 €	%	FLE	%
Biobased energy				
Biobased gas	38	3.4%	374	4.0%
Biobased electricity	89	8.0%	456	4.9%
Biobased heat	210	18.8%	842	9.0%
Biobased fuels	25	2.2%	146	1.6%
Sum	325	29.4 %	1444	15.4 %
Biobased products				
Paper	215	19.3%	1546	16.5%
Fiberboards	256	22.9%	1991	21.3%
Biobased plastics	52	4.7%	847	9.1%
Biobased chemicals	268	24.0%	3532	37.7%
Sum	791	70.9 %	7916	84.6 %
Total bio-based economy	1116	100.0%	9361	100.0%
Total Flemish economy	60,949		2,585,296	
Percentage bio-based	1.8 %		0.4 %	

Note: FLE means Full –time Labor Equivalents.

4.2. *Step 2 – definition of the optimal level of disaggregation*

Whichever concept is used, it is clear that the bio-based economy is very broad. It is basically an economy in which all or some building blocks (depending on the chosen definition in critical point 1) come from renewable resources, namely biomass. The size of the bio-based economy can only be established by defining recognizable categories and sub-categories that can be measured in official statistics. The first category is bio-based energy and consists of fuel, heat and electricity production. The second category summarizes all other bio-based products including products from forest biomass (such as paperboard or pellets), agri- or horticultural biomass (such as bioplastics or biofibres) and white or red biotechnology (such as biochemicals).

Further subdivisions can always be made leading to groups of specific endproducts, such as bioplastics based on PLA (poly lactic acid) or clothing based on bio-fibers. To decide on the optimal level of subdivision, advantages and disadvantages of further disaggregation should be weighed. Having only few subdivisions will have the advantage of giving a clear and straightforward result, easy to understand by anyone interested in the bio-based economy. Furthermore, measurement errors have a smaller potential to bias the relative shares of sub-categories. Having many subdivisions will have the advantage of more detailed results, although it will take more time and effort to collect all data. The appropriate balance will depend not only on the study's specific context, but also on the addressed target group (see Fig. 3): policy makers, the industry, nature associations, research institutes and so on. A clear description of the level of disaggregation will make the results of different studies comparable.

4.3. *Step 3 – mapping all bio-based companies*

The study's specific context and the chosen subdivision will influence the data to be collected (see Fig. 3). For example, information on the production of bio-based energy (as a chosen subdivision) is abundant. Almost every power producer and supplier in Flanders, and for that matter also in Europe, has taken up a green product for the purpose of image creation. Each one of them wants to be profiled as a company concerned about GHG emissions. In Flanders, e.g., all energy producers have their own plan: Electrabel has its plan "Together for less CO2" [31], Spe-Luminus creates "energy for generations" [32], and Eneco claims to be the "most complete negotiation partner for sustainable energy projects" [33]. The

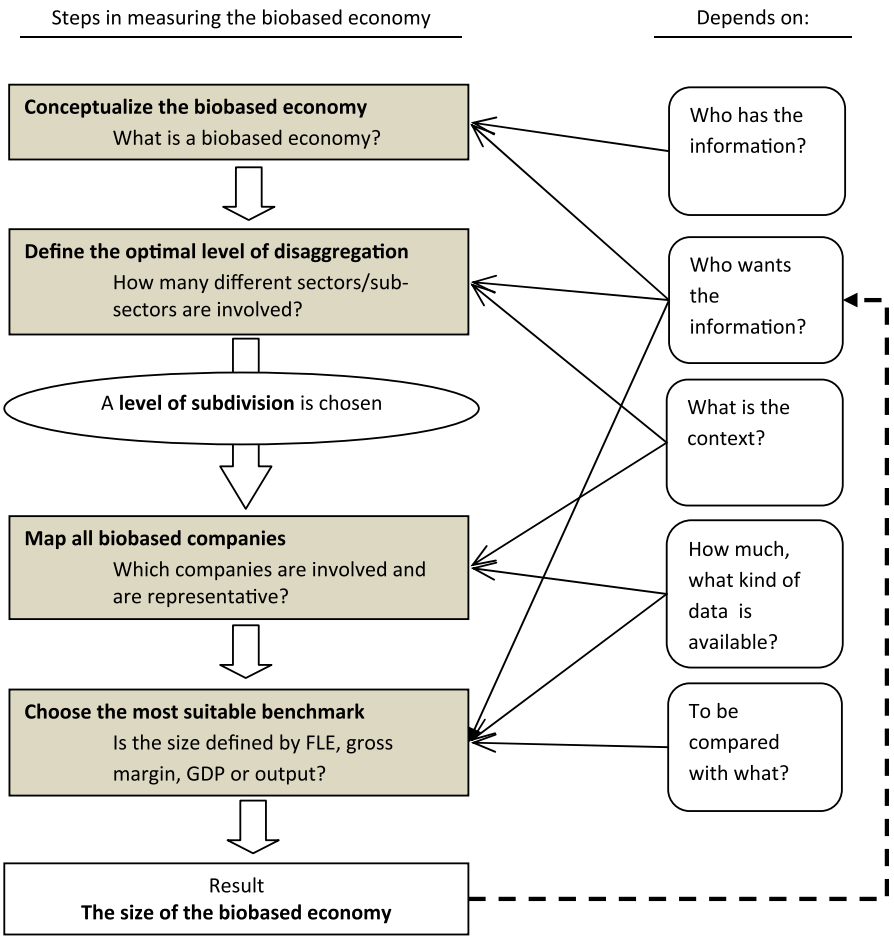

Fig. 3 – Framework to measure the size of the bio-based economy.

same holds for fuel companies who all have a brand in their portfolio that is a biofuel blend, for example the Excellium Gasoline of Total contains up to 15% of bio-based ethanol and the Excellium Diesel of Total contains up to 5% of biodiesel [34]. However, information on bio-based products as a subdivision is much harder to find. Mostly, because this subsector is very diverse, but also because many products and companies are just partly bio-based.

Mapping can be done by searching for representative bio-based companies, interviewing them and asking to indicate their competitors (snowball sampling). Based on these interviews the share of bio-based in their total production can be estimated. This figure can then be extrapolated to the production of other companies in the same (sub-) sector.

4.4. *Step 4 – using the most suitable economic benchmark*

Finally, the estimated size of the bio-based economy will depend on the type of economic benchmark used: in GDP [3], in market value of the finished product [8], in mass [6], in output [7] or any other unit. The choice has to be made looking at both comparability with other studies and availability of data (see Fig. 3). In the case at hand, it was decided to work with two economic criteria: gross margin of a firm and number of employees. The results are compared with the total gross margin and employment records of the Flemish economy to correct for general economic fluctuations, because no time series were available.

Again, it will be important to know who wants the information: policy makers, the private sector or scientists. Each of these actors is more familiarized with specific benchmarks, e.g. while policy makers will be more interested in the impact on employment, the industry might be more interested in production or value added.

The result of measuring the size of the bio-based economy has to flow back to those interested in the information (shown by the dotted arrow in the figure). This will be in the first place policy makers who need baseline indicators of the bio-based production before they can start formulating and implementing policy actions. Because these policy actions will again trigger the need for other information, the framework describes a process emphasizing the important role of policy makers.

5. Conclusion

To conclude, it can be stated that:

- research on the bio-based economy in general is not often reported in scientific literature;

- several methods have been used to measure the size of the bio-based economy, leading to a multitude of estimates, often incomparable with each other;
- in Flanders a small part of the economy is bio-based, namely 1.8% of the gross margin – an estimate dependent on specific critical points;
- a framework for estimating the size of any bio-based economy should be developed, including a conceptualization of the bio-based economy, the optimal level of disaggregation, a mapping of all companies and the most suitable benchmark, leading to comparable and robust estimates.

Although estimating the size of the bio-based economy has not often been reported before, we think that such a study is of major importance for current and future discussions on the bio-based economy. Firstly, policy makers need to have baseline information estimating the status of the bio-based economy today in order to develop adequate policy measures. Secondly, firms need to know how bio-based the current economy is, in order to position themselves in relation to their competitors. Thirdly, a solid estimate will enable the comparison between regions and countries, at different times.

However, such an estimate is not always straightforward neither easy to calculate, as was shown by the Flemish case described above. The most important consequence of this is that figures published or used are difficult to compare both in time and amongst regions. The main reason is that each study often uses its own definition of bio-based economy. We suggest using a clear, holistic and uniform definition throughout all future studies. Although the optimal level of disaggregation depends on the development stage of the still infant level of these sectors and can be specific to each study, the classifications used should be described in detail so that the results can be interpreted correctly. In order to enhance comparability between regions, internationally comparable official statistics would be of great value. A suggestion could be that firms need to report in their statistics the share of bio- and fossil-based inputs in their production process.

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