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# Environmental Innovation Policy – Greater resource efficiency and climate protection through the sustainable material use of biomass

Short version



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## **Environmental Innovation Policy - Greater resource efficiency and climate protection through the sustainable material use of biomass**

### **Short version**

by

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## Abbreviations

CEPI	Confederation of European Paper Industries
EEG	German Renewable Energy Act ( <i>Erneuerbares-Energien-Gesetz</i> )
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Office
FiFo	FiFo Institute for Public Economics at the University of Cologne ( <i>Finanzwissenschaftliches Forschungsinstitut an der Universität zu Köln</i> )
FNR	Agency for Renewable Resources ( <i>Fachagentur Nachwachsende Rohstoffe e.V.</i> )
IFEU	Institute for Energy and Environmental Research Heidelberg GmbH ( <i>Institut für Energie- und Umweltforschung Heidelberg GmbH</i> )
I-O	Input-Output
ISCC	International Sustainability and Carbon Certification
ISO	International Organization for Standardization
Nawaro	Nachwachsende Rohstoffe
nova	nova-Institut GmbH
PDO	1,3-Propanediol
PLA	Poly lactide
PS	Polystyrene
R&D	Research and Development
RED	Renewable Energy Directive
REMD	Renewable Energy and Material Directive
UBA	German Federal Environment Agency ( <i>Umweltbundesamt</i> )

## 0 Objectives and methodology of the research project

nova-Institut GmbH (coordinator), the Institute for Energy and Environmental Research Heidelberg, (IFEU), FiFo Institute for Public Economics at the University of Cologne (FiFo) and the Öko-Institute e.V. were commissioned by the Federal Environment Agency to carry out the research project “Environmental Innovation Policy – Greater resource efficiency and climate protection through sustainable material use of biomass” from 2010 to 2013.

The overarching goal of the research project is to develop strategies and instruments for sustainable material use of biomass in order to contribute to the German federal government’s climate protection and resource conservation objectives. Political debate about biomass in recent years has focussed primarily on energy use. Clear development objectives were set for the use of bioenergy and a number of instruments introduced to promote it. There are, however, no binding objectives and few supporting measures for the material use of biomass. Yet for some time now sustainable material use of renewable resources has become a growing preoccupation for both politicians and the industry. In the future, fossil resources are to be increasingly replaced by biogenic raw materials, i.e. renewable carbon sources. Industry is still largely dependent on fossil resources.

That is the backdrop against which the Federal Environment Agency (UBA) is funding this research project. The main concerns of the project are the sustainability requirements and resource efficiency of the industrial material use of biomass, for such material use should not lead to new environmental pollution or exacerbate existing environmental problems. The project therefore explores the major environmental themes that have been a significant feature of current discussions on bioenergy use: avoiding greenhouse gas emissions, and conserving and protecting biodiversity along with soil and water resources. Questions of economic and social effects are also relevant in the context of material use of biomass. The following major areas are highlighted to achieve the project objectives:

- Gathering data on biomass flows for material use in Germany, Europe and worldwide;
- Identifying environmentally and quantitatively relevant value chains in which biomass can be a substitute for abiotic resources;
- Evaluating the land and resource efficiency of the potential substitution of fossil resources with biomass;
- Assessing the environmental impact of material use over the entire life cycle;
- Analyzing the macroeconomic effects of material use of biomass regarding added value and employment;
- Developing a comprehensive methodology for assessing the sustainability of biomass-based products or bio-based raw materials;
- Identifying existing barriers and shortfalls, as well as possible political and legal courses of action to support material use of biomass;
- Developing strategies and instruments to increase resource efficiency through sustainable material use of biomass;
- Developing future scenarios for the material use of biomass and deriving policy recommendations from them.

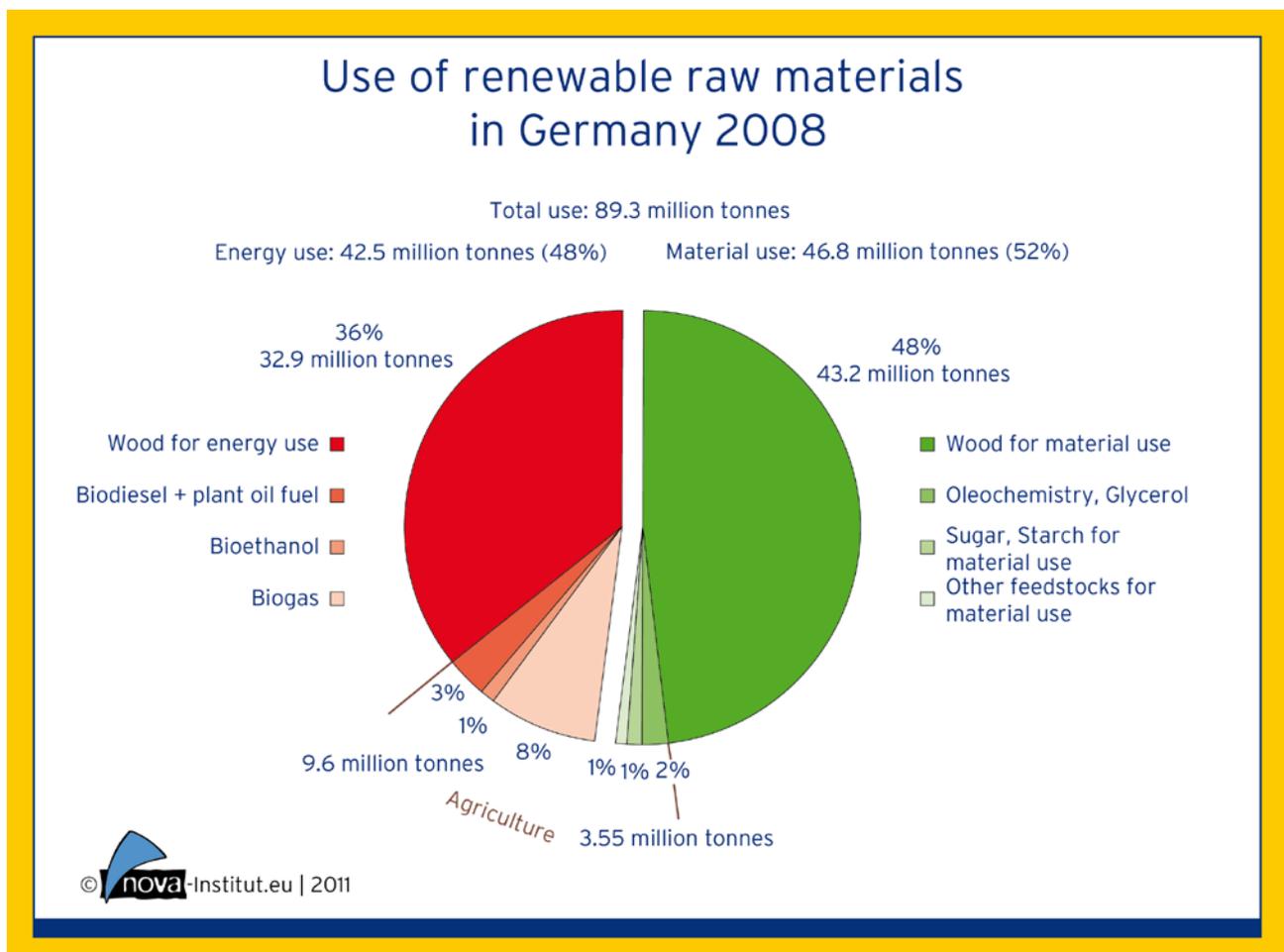
The long version of the final project report includes a detailed description of the core themes divided into a total of nine work packages. This short report presents a summary of the research findings.

## 1 Available data on biomass flows for material use in Germany, Europe and worldwide

In this study, the term “material use” is used to mean the following: “In ‘material use’ biomass serves as a raw material for the production of all kinds of goods, as well as their direct use in products. This distinguishes it from energy use, where biomass serves purely as an energy source.” (Carus et al. 2010)

The study provides an overview of the available data on material use in Germany, Europe and worldwide, most of which takes 2008 as the year of reference. The data for Germany was mainly based on updated and expanded versions of Carus et al. 2010 and Knappe et al. 2007. Figures for Europe and the rest of the world were collected using an updated version of a methodology that had previously only been utilized in Germany. To do this, the major agricultural and forest resources (production and imports) are entered into a matrix and quantified according to use.

Figure 1: Use of renewable raw materials in Germany in 2008. Comparison between energy and material use.



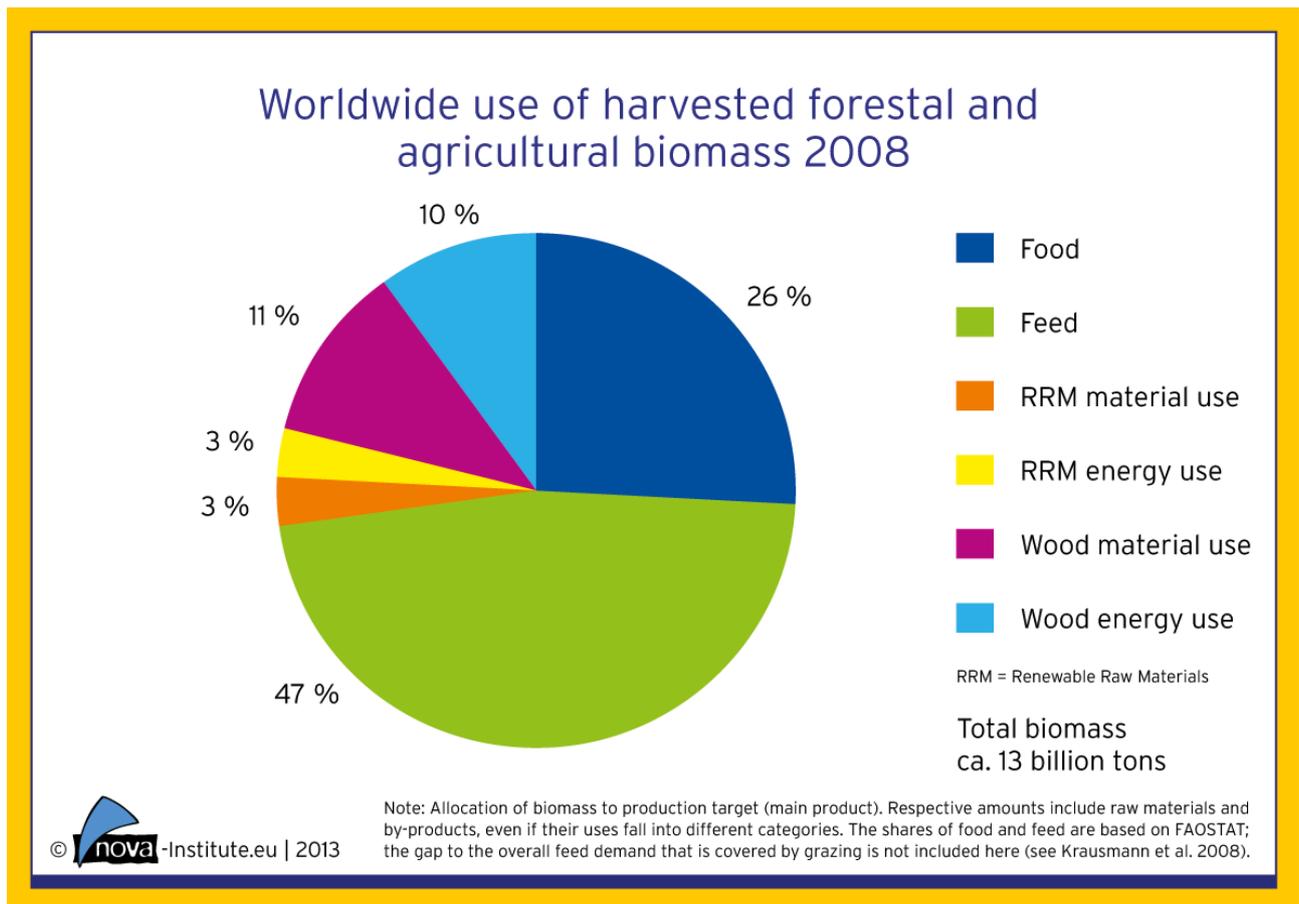
nova Institute 2011

This provides a comprehensive picture of all biomass flows, showing the volumes of biomass used for food and feed production, material and energy use respectively. There is also a comparison between biomass use and the use of other mass raw materials such as steel and concrete (see Figure 3).

The total volume of material use of renewable resources was 46.8 million tonnes in 2008 compared to a total volume of renewable resources used for energy of 42.5 million tonnes. These volumes do not include the use of straw, other crop waste, and residues, which, apart from being used to produce biogas for energy, are utilized above all in agriculture for compost, animal litter and fertilizer production. We are no closer to being able to accurately and systematically quantify the volumes of these materials that are actually used for industrial materials. Overall, the volume for material use (52 %) slightly exceeds that for energy use (48 %). Widening the data analysis to Europe and the world shows that industrial materials always account for a slightly higher proportion of biomass use than energy.

However, even when taken together, both of these sectors account for only a small proportion of agricultural raw materials compared to their use in the food and animal feed sectors. The worldwide harvest of total biomass as agricultural and forest biomass is about 13 billion tonnes (FAO 2011). 3 % of this is used for energy and another 3 % for materials; 10 % of the total biomass is wood for energy and 11 % of the total biomass is wood for materials. Overall, approximately 26 % of the forest and agricultural biomass harvested worldwide is destined for use as industrial materials. The vast majority goes towards producing animal feed (47 %) and food (26 %).

Figure 2: Use of harvested forestal and agricultural biomass in 2008

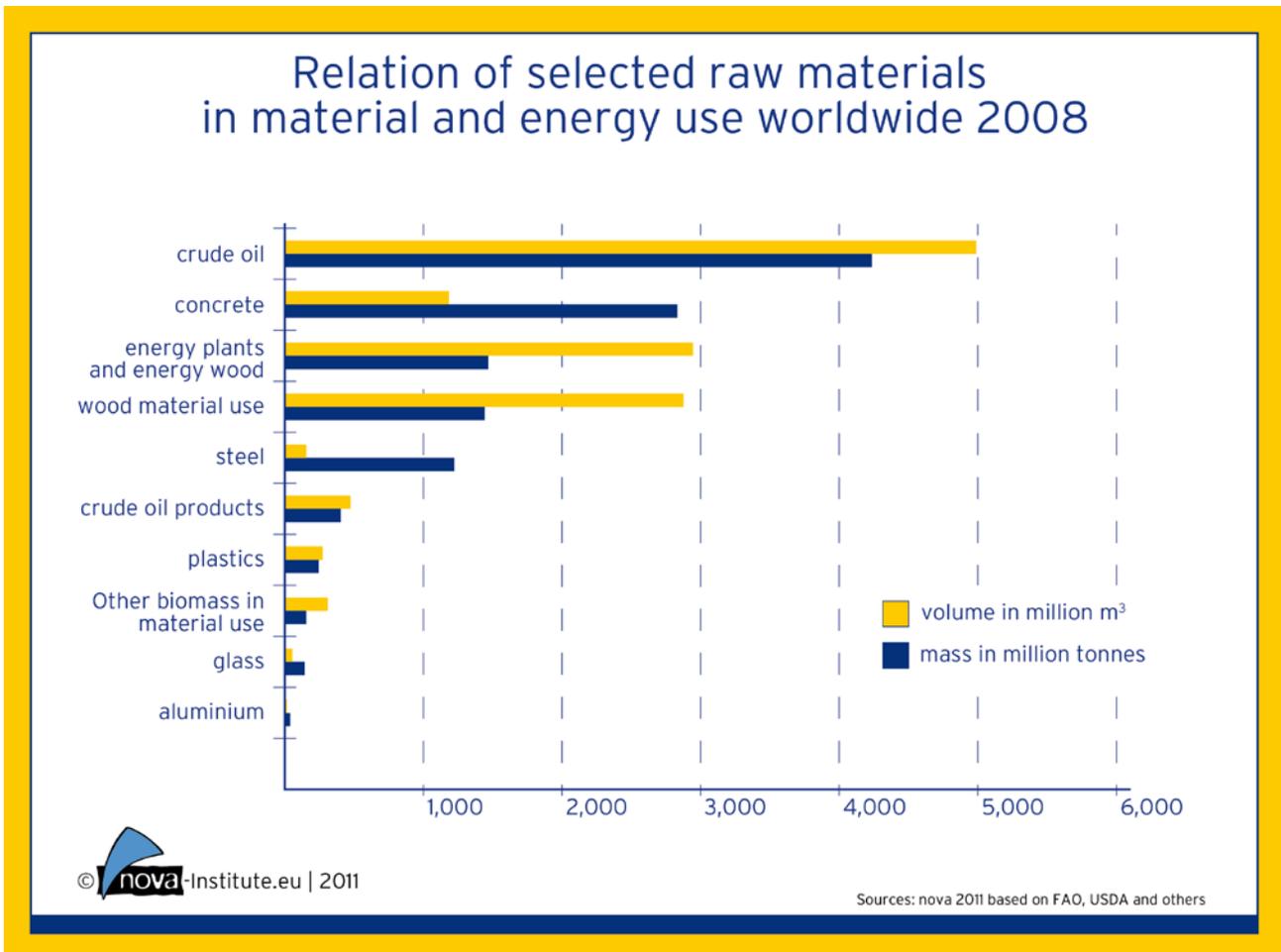


nova Institute 2013, based on FAO 2011 and Krausmann et al. 2008

In comparison to other raw materials used around the world, renewable resources – and in particular wood – account for a very large share of the whole, their mass being roughly

equivalent to concrete and steel. In volume terms, industrial material and energy uses of renewable resources combined exceed those of all other raw materials.

Figure 3: Relation of selected raw materials in material and energy use worldwide, 2008



yellow: volumes in millions of m<sup>3</sup>; blue: mass in millions of onnes; nova Institute 2013

The following figure shows which renewable resources are used as a raw material by which sectors' processing industry. Wood, starch and vegetable oils are the main biogenic resources for material use by volume, followed by rubber and sugar. Yet biogenic residues and straw already play an important role. Chemical precursors, plastics and composites, detergents, lubricants and cellulose-based chemical fibres have been identified as the main growth markets.

You will find many more tables and figures in the long version, which will give you a comprehensive and detailed overview of the use of biomass for industrial materials in Germany, Europe and worldwide for different resources and different applications.



## 2 Potential substitution of abiotic resources

The second work package examines to what extent some fossil-based raw materials can be replaced by bio-based raw materials/products. The underlying criteria for the selection of potential substitute pairs are relevant quantities and environmental relevance.

Abiotic material flows that are produced in large quantities and can be replaced by biotic products on a large scale are deemed to have “mass relevance”. In order to identify the environmental relevance, it is appropriate to concentrate on a few prominent indicators. As the greenhouse gas balance is regarded as being a fairly representative expression of many environmental effects, greenhouse gas emissions are used as a measure of environmental relevance when identifying abiotic material flows.

Fossil-based organic compounds, 90 % of which are made from oil in the case of Germany, form the largest group of products that could potentially be replaced by organic biogenic compounds. Products in the group of mineral and metal materials that are particularly eligible for substitution by biogenic materials are concrete, steel, mineral wool, fibreglass, iron and steel, aluminium and copper.

Only 4 % of the fossil raw materials used each year in Germany go into producing industrial materials. The manufacturing chain generally proceeds in several stages from simple compounds (e.g. ethene) via intermediate products (e.g. ethylene glycol to final material products (e.g. polymers or fibres). Fundamentally, there is the potential for substituting materials at every stage. However, life-cycle analyses will be required to determine their environmental benefits.

Every product group we investigated – basic chemicals, plastics, mineral products and metals – can be defined as environmentally relevant due to its specific value. When this is combined with their quantity relevance, all plastics, polyamide, ethylene dichloride, vinyl chloride, propene, propylene oxide, benzol, aluminium and construction steel were identified as being highly relevant for potential substitution with bio-based raw materials. On the basis of these criteria, six pairs of substitute products were selected (see Table 1), and these will be examined in more detail in the following work packages.

Table 1: Selected product pairs

Group of products	Raw material	Product line	Substitution partner
Alcohols	Sugar, starch, lignocellulose	1,3-Propanediol (PDO)	1,3 Propanediol (petrochemical)
Plastics	Sugar, starch, lignocellulose	Poly lactide (PLA)	Polystyrene
Cellulose & paper	Wood	Packing paper	Polyethylene film
Insulation	Wood	Wood fibre insulation	Mineral wool
Composites	Hemp	Hemp fibre composite	Fibreglass composites
Cascading use of wood	Wood	Solid wood - wood composites - heating	Steel girders - sheet steel - power and heat production mix

### 3 Evaluation of value chains

The objective of Work Package 3 is to highlight efficient value chains for the production of materials. Model value chains and material flows are also evaluated regarding their potential to improve sustainability by increasing the material use of biomass. The evaluation was carried out using an assessment matrix containing a number of environmentally relevant indicators in particular. The following groups of indicators were selected:

- Resource efficiency,
- Environmental efficiency,
- Land efficiency,
- Cost efficiency.

We investigated six product pairs in total (see Table 1).

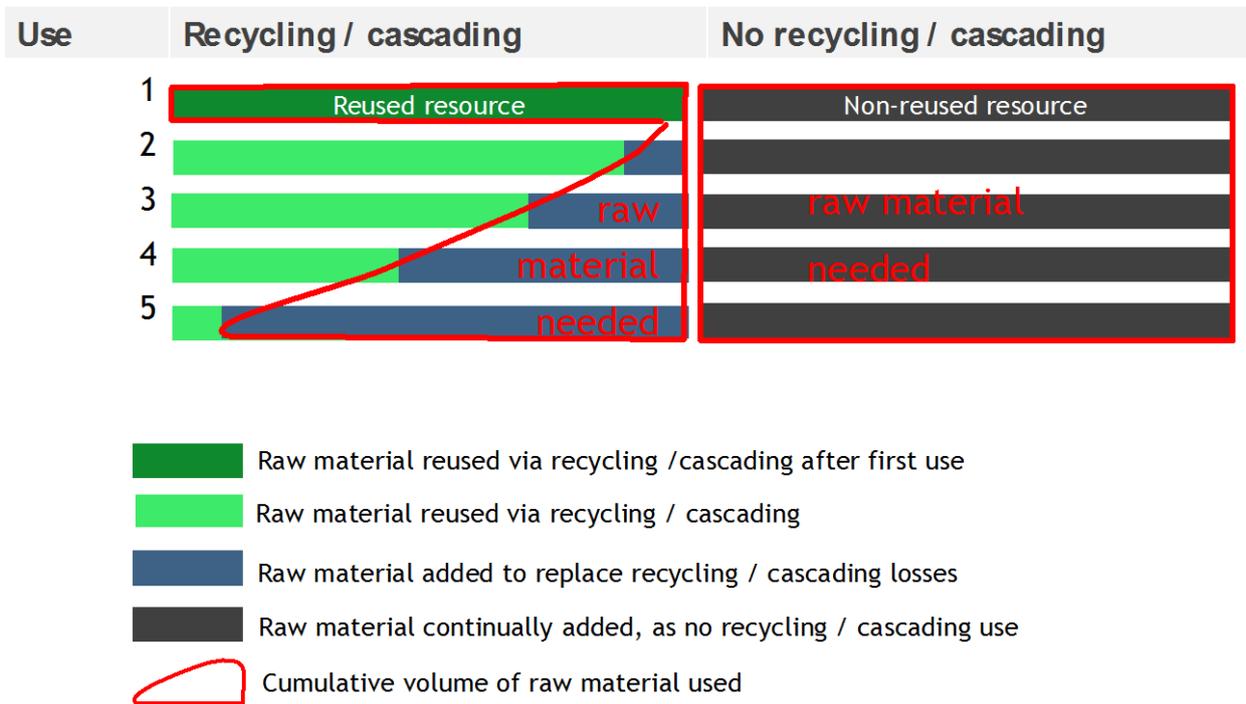
Our research comes to the conclusion that the applicable indicators show that the selected bio-based products have both advantages and disadvantages compared to their respective conventional reference products. The assessment indicates a fairly good balance between environmental and economic advantages and disadvantages for bio-based products produced from agricultural biomass (e.g. 1,2-Propanediol, which is contained in solvents and toiletries, or polylactic acid, a bio-based polymer). However, when wood is used as a primary material (paper, insulating panels, building materials with cascading use), just about all the indicators reveal benefits, for example in terms of greenhouse gas emissions, acidification during the life cycle, and resource consumption in terms of fossil resources and abiotic raw materials. The exceptions are biogenic raw material consumption and land consumption.

One other fundamental task involved defining and applying the indicators to the six substitution pairs and testing whether the set of indicators that had been developed would work when applied to the assessment of scenarios covering the whole material flow, as in Work Package 9. In general this proved feasible, since meaningful results can be presented for all indicators (with the exception of cost efficiency). For the scenarios, though, the indicators must be applied to a far wider range of products. As no separate life-cycle assessment was carried out for any products not covered by this study, Chapter 9 also contains data from other studies, along with general data from available databases.

The study highlights that the avoidance of cumulative demand for primary resources is particularly relevant to specific assessments of multiple or cascading use of biomass. A comparative analysis at the same level of use (functional unit) does not bring out the cumulative dimension as clearly as a study of inputs would do. This has already been applied many times to life-cycle analyses of closed-loop systems. It has so far been methodologically difficult to do the same for cascading use that draws on a wider range of substitute materials. For reasons of consistency, these different material flows can be presented alongside each other but not in combined form. A “multiple use factor” or “resource extension factor” could however be added to the life-cycle assessment by way of additional information. Analyzing the overall effects of such complex cascading uses would require an analysis of all the material flows linked to the cascading uses, but that is beyond the scope of this R&D project.

When assessing value chains involving recycling or cascading use (the use of waste and residues), one must take into account that a share of the initial material input proceeds to a new or another phase of usage after its primary utilization. The higher this proportion is, the higher the sum of the primary resource consumption that is actually avoided over time.

Figure 5: Diagram showing cumulative raw material consumption for reused and non-reused raw materials.



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## 4 Life-cycle assessment for selected bio-based products

Work Package 4 quantifies the environmental effects of the use of biomass for materials by means of several case studies. The goal here is to provide an environmental assessment of material use of biomass along with recommendations for decision-makers.

So-called screening life-cycle analyses are carried out for the selected and identified product pairs with reference to ISO standards 14040 and 14044 (ISO 2006). The analysis of bio-based products is systematically carried out in comparison with the respective abiotic substitute (conventional reference product) and taking account of the entire life cycle in both cases. The analysis focuses less on ascertaining LCA results to the nearest decimal place and more on:

- Showing the methodological specificities of material use of biomass; and
- Identifying the parameters that affect the results and determining their impact through sensitivity analysis.

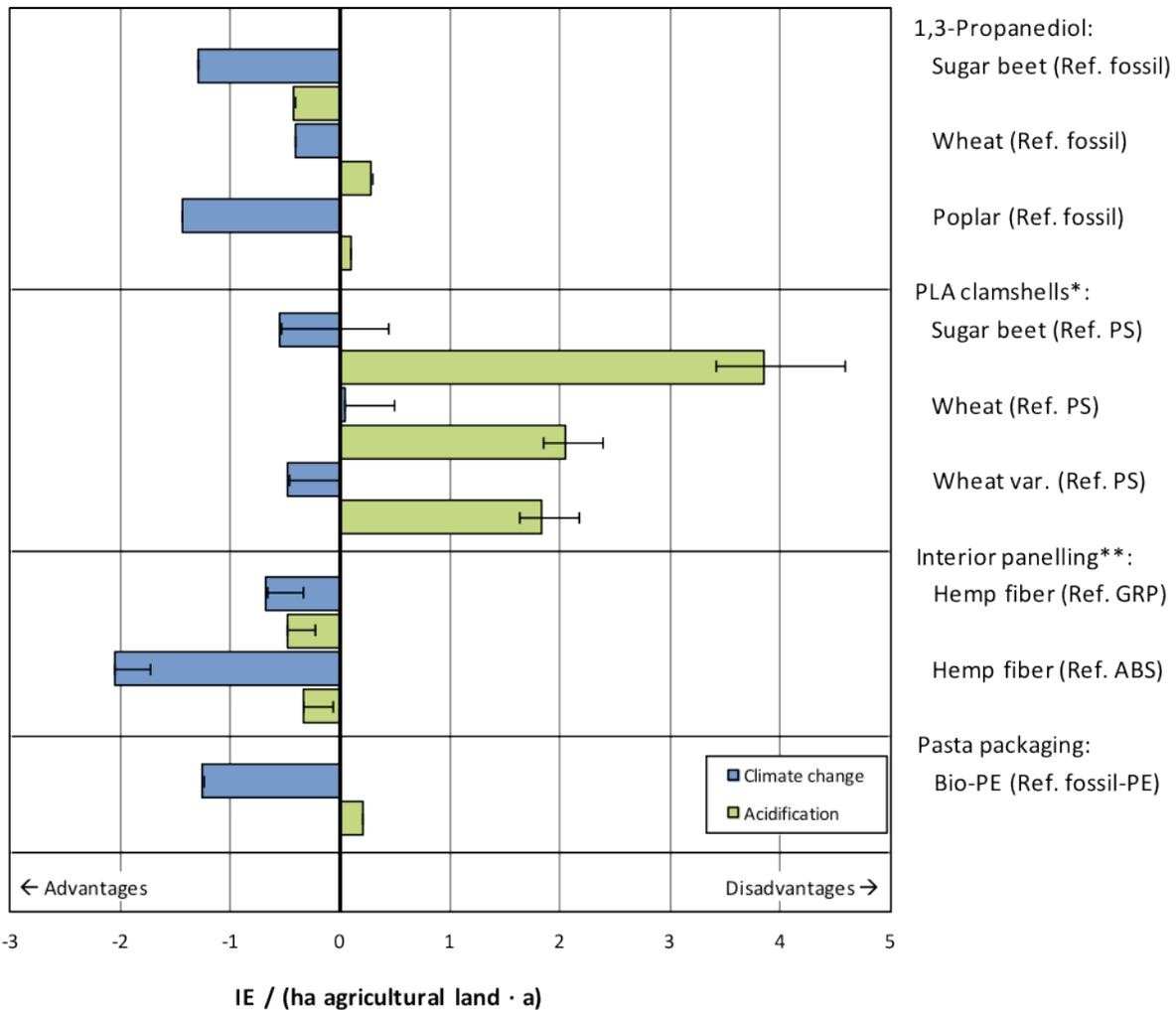
Every bio-based product is therefore subjected to sensitivity analysis using variable individual parameters. To make up for this, the number of case studies tested is restricted to the six given in Chapter 2. The aforementioned elements are supposed to help to achieve an environmental assessment of the material use of biomass and to provide some recommendations for decision-makers.

In light of the life-cycle assessment results, it can be concluded that bio-based products have environmental advantages and disadvantages and show many parallels to energy use of biomass. Figure 6 offers a fine illustration of life-cycle analyses for bio-based products from crop biomass for two impact categories. As for energy use, life-cycle assessment generally displays no clear-cut benefits or disadvantages for material use.

Some positive exceptions to this rule are shown by wood-based life cycles, which can have environmental advantages, especially when the greenhouse effect and non-renewable energy input are taken as primary impact categories. There might be a need to re-assess this should rising demand for wood in the future lead to significant changes in biodiversity. Thus restricting the environmental assessment to just a few indicators such as the greenhouse effect and non-renewable energy consumption is only permissible in exceptional cases. A comprehensive life-cycle assessment requires the widest and most meaningful set of impact categories possible, as specified by ISO 14044.

The following figure shows the results of the screening life-cycle assessment for some bio-based products from crop biomass in the impact categories of climate change and acidification.

Figure 6: Life-cycle assessment results for the impact categories climate change and acidification for bio-based products compared to their conventional reference products, presented as per inhabitant equivalents per hectare of land and year.



\* : The range given includes the reference products PP and PET.

\*\* : The range given shows the use of shives as animal bedding.

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The research also shows that life-cycle assessment is an appropriate instrument for quantifying the environmental impact of bio-based products. However, the results for the products studied here should not be automatically transposed to other bio-based products, as individual products may diverge from these findings. The selected case studies do indeed cover various areas of application for the material use of biomass, but they are not sufficient to allow for a general environmental assessment. Equally, the performance of a single product does not allow any conclusions to be drawn about the overall performance of the raw material from which it is made.

Unlike life cycle analyses of bioenergy sources, life-cycle analyses of bio-based products are less, or not at all, suited to standardization, as the usage and disposal phases can turn out very differently. If one takes the example a clamshell, one sees that a brief inspection of the bio-based life cycle – e.g. so-called “cradle-to-grave” inspections, which end with the manufacturing of the polymer – is not advisable, since the choice of the conventional reference product (conventional clamshells made of PS, PP or PET are possibilities, depending on how they are

used) and the resulting different disposal paths are of great relevance to the life-cycle assessment of the PLA clamshell.

The comparison between the environmental impact of using biomass for materials and energy shows that bio-based products are at least equal to bioenergy sources. For instance, net greenhouse gas savings per land area when biomass is used for materials lie within a similar range to energy use – and are in some cases significantly higher. There is therefore, from an environmental conservation perspective, no reason to favour bioenergy production from biomass over material use<sup>1</sup>. From a food security viewpoint, it would be more sensible to channel biomass towards material use and to emphasize the role of biomass as the only currently available renewable carbon source<sup>2</sup>, in the chemical industry for example. High specific energy and greenhouse gas savings compared to petrochemical reference products can, for instance, be achieved by using natural photosynthesis to produce more valuable compounds.

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<sup>1</sup> Thanks to applicable supporting measures, the overwhelming majority of renewable resources are currently used for renewable energy production, even though alternatives would be available for this purpose.

<sup>2</sup> Aside from power-to-gas technology, which could potentially use surplus green electricity in the future to convert hydrogen and methane (which can be used both for materials and energy).

## 5 Macroeconomic effects

Work Package 5 examines the macroeconomic effects of material use of biomass through input-output analysis. Added value and employment were the parameters under investigation. This is a major methodological challenge, since material use has been the subject of far less study than energy use. The work package's central questions are therefore:

- What impact does substituting a fossil-based product with a very similar bio-based product have on macroeconomic parameters?
- Can the input-output analysis commonly used in the energy field be applied to analyses of material use? What kind of problems does this raise?

Two representative substitution pairs were selected and investigated using available data and the potential for inclusion in input-output analysis. The selected products are insulation materials (wood fibre insulation vs mineral wool) and plastics (polylactide vs polystyrene). While the demand for intermediate goods (including forestry and chemical intermediate goods) is on the rise due to the process of substitution by wood fibre insulation, there is a noticeable throttling of added value in the stone and earth and electricity intermediate sectors. The overriding effect on domestic demand is likely to be positive. For plastics, the effect on German agriculture is extremely positive due to rising demand for maize. Some slightly negative effects on added value can be discerned in the substitution of petrol derivatives and electricity supply. Positive effects on employment are to be expected given the labour-intensive nature of agriculture.

The study comes to the conclusion that the selected methodology can only be applied in limited cases due to the complexity of the materials sector and the incompleteness of the available data. In general, an acceptable level of data collection is required to give a statistical snapshot of the macroeconomic effects of individual substitutability. However, as soon as the analysis seeks to take a wider view (i.e. to give a comprehensive overview of every substitutability possibility) and, in addition, to include dynamic long-term developments, then the costs of collecting the necessary data are far higher than the benefits. Answering these questions in a substantiated manner would require more in-depth and detailed studies. We propose an alternative methodology: a top-down analysis of successively higher branches of industry that generates approximate figures with an acceptable level of investment.

### Meta-analysis

The research project augmented the input-output analysis with a comprehensive meta-analysis, which evaluated the major current studies on the economics of material use. This meta-analytical study of the macroeconomic effects focussed on the question: "How do we assess the economics of material use compared to energy use?" using the same parameters of added value and the effects on employment. Our study of these macroeconomic effects considers direct gross effects and does not take account of indirect effects and substitution effects (net effects). The parameters are:

- Direct gross employment,
- Direct gross added value.

The meta-analysis took account of upstream process stages in the form of primary forestry production, for example. It also considered only those production stages in which the macroeconomic effects can be traced back to the raw material and in which the raw material constitutes a significant part of the added value and employment.

The following table shows the results of the studies of the added value and employment generated by energy and material use evaluated in the meta-analysis, as well as our own calculations.

**Table 2:** Results of the studies of the added value and employment generated by energy and material use evaluated in the meta-analysis, as well as our own calculations.

Study	Contents	Study calculating the factors	Direct gross employment factor*	Direct gross added value factor*
Case study: Gothe/Hahne (2005), after recalculation	Regional added value using the example of a German wood cluster	Carus et al. (2010)	-	4 to 9
Input-output analysis: Pöyry (2006)	Added value and employment in the paper and cellulose industry compared to energy use	Carus et al. (2010)	ca. 10	ca. 6
Input-output analysis: CEPI & Pöyry (2011)	Added value and employment in the paper and cellulose industry compared to energy use	Dobroschke et al. 2013 (as part of this project)	ca. 7	ca. 5
Input-output analysis: Nusser et al. (2007)	Macroeconomic effects of the production and use of renewable resources	Carus et al. (2010)	(3-5) to 19	-
Cluster study forestry and wood: Seintsch (2008)	Macroeconomic effects of the forestry and wood cluster in Germany	Dobroschke et al. 2013 (part of this project) Carus et al. (2010)	ca. 6 ca. 7	-
Case study: hemp insulation compared to vegetable oil fuel (rape) Carus et al. (2010)	Comparison of 1 ha of hemp for insulation with 1 ha of rape for vegetable oil fuel	Carus et al. (2010)	ca. 8	-
Industry data (our calculations)	Employment and turnover in German industries	Dobroschke et al. 2013 (part of this project), Carus et al. (2010)	ca. 5 > 6	ca. 7.5 > 8-9
Typical ranges from the named studies and calculations (recalculations)			(3) 5-10 (19)	4-9

The factors state how much more gross employment and added value is created per unit of land (or tonne of biomass) by material use than by energy use.

Overall, it is apparent that material use promises several advantages over energy use in terms of gross employment (Factors 5-10) and gross added value (Factors 4-9) - in both cases related to the same area of land or volume of biomass. This is largely due to the considerably longer process and value chain for material use.

A study of the net effects, on the other hand, were to show a far smaller impact, as these take account of the decline in production caused in a specific sector by expanding production in a different sector. The far higher gross added value and employment one sees are primarily the result of material value chains being considerably longer than energy ones. If one factors in the net effects, then this impact is reduced, since petrochemical value chains for materials are also much longer than those for energy. A robust calculation of the net effects was not possible in this project due to a lack of data and an uncertain methodology. We estimate that the positive effects of material use would still be visible, but they would tend to be between 1.5 and 2 rather than between 5 and 10. One final remark is that it is standard practice to give the gross effects when comparing industries and value chains, since the data and methodology problems we have described generally apply.

## 6 Approaches for assessing the sustainability of material use of biomass

The goal of Work Package 6 is to put forward a system for evaluating the sustainability of the use of biomass for material use. This system should serve as a basis for assessing the sustainability of material biomass use and as a decision-making tool for politicians, the public and business.

The sustainability assessment system was developed on the basis of existing sets of criteria. These arose in recent years as part of the discussion about the sustainability of using bioenergy and biofuels, their sources including legal regulations, standardization processes, agreements and certification systems. As a first step, we therefore listed the criteria that feature in the main systems for energy use of biomass along with agriculture and forestry, and then assessed their suitability for evaluating the use of biomass for industrial materials.

In doing this, one must keep in mind that such systems form a binding and effective verification procedure to justify political supporting measures (mandatory quotas, tax incentives). These supporting measures are not yet in place for materials from biomass, making it difficult to establish such verification systems. At this point in time, it is therefore a matter of generally integrating the use of biomass for materials into the sustainability discussion and showing the compatibility between this discussion and material use.

The analysis and the subsequent development of an assessment system are based on groups of environmental and social themes that are considered to be particularly relevant to debates about the use of biomass for materials, which are:

- Reducing greenhouse gas emissions,
- Conserving and protecting biodiversity, soils and water resources,
- Social criteria,
- Competition for land, changes in land use and land efficiency,
- Genetically modified organisms (GMOs),
- Links to global issues such as the utilization of agricultural raw materials, sustainable land use, food security, energy policy and international trade.

Closer study reveals that the criteria of the sustainability systems we studied in the field of biomass use for energy are largely transposable to material use. This is only natural, because:

- Material use generally lays claim to the same raw materials; and
- The greatest potential conflicts over sustainability arise at the level of raw material production (cultivation).

Most of the established criteria refer to cultivation or land use or to potential changes in land use. These are exclusion criteria where non-compliance clashes directly with the principles of sustainability, and they can therefore be applied to biomass for material use in the same way. The EU Renewable Directive (EURD), the only existing legally binding instrument, includes guidelines for assessing the sustainability of biofuels and is therefore a suitable basis and example for a sustainability assessment of material uses of biomass.

Generally speaking, the sets of criteria we studied address the aspects listed above, although different systems must be consulted depending on the underlying raw material. The criterion of saving greenhouse gas emissions does, however, require some amendments. For it to be sustainable, material use should lead to savings in greenhouse gas emissions. If one takes the

EURD's methodological guidelines as a template, then there is a need for methodological adjustments, given the wide range of life cycles involved in material use. Biofuels are a mass-produced good and, as a rule, the greenhouse gas emissions can be calculated along the supply chain for each cycle according to one simple value index (energy content in MJ) as stipulated by EURD rules. However, this is far more complex for the life cycle of a bio-based material product. Also, it is only the corresponding supporting measures for biofuels that make the considerable cost of such calculations worthwhile.

Yet since bio-based product manufacturers are interested in harmonization and standardization – as demonstrated by ongoing work at CEN level – it is more a matter of standardizing the calculations for proper, systematically comparable values for specific product cycles. This will apprise manufacturers at industry level and policymakers for products and product design of their impact on the climate. The methodological approach presented in this paper makes this possible.

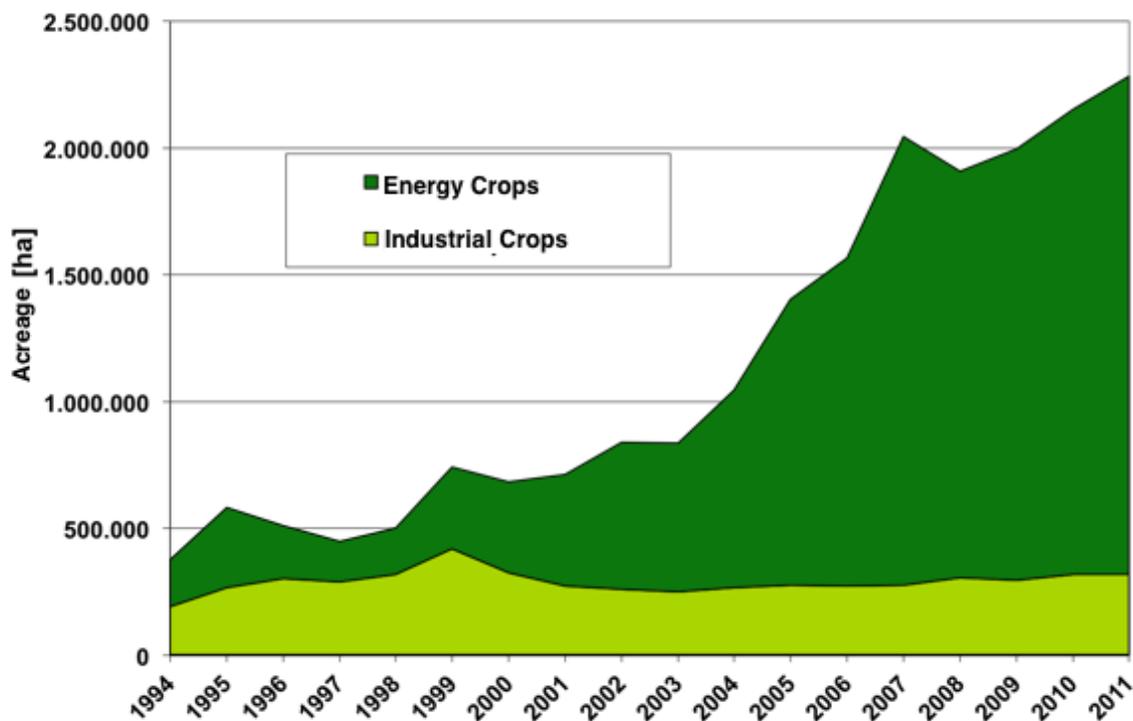
The methodological approach leads to a proposal for an overall system of sustainability assessment for the material use of biomass. Yet before we set out hard-and-fast requirements for sustainability assessment for the material use of biomass, we must define the objective and the purpose of this assessment and who will actually make use of the assessment. The choice of criteria and their practical application will differ significantly according to whether it is individual products that must prove their compliance with sustainability criteria (e.g. after the introduction of supporting measures) or whether the assessment is to be applied at a higher level for an entire branch of industry - for instance to draw up policy strategies. The proposal developed during this R&D project is aimed at the latter. With the exception of the more complex situation regarding greenhouse gas emissions, all of the proposals detailed here can also be used to provide individual pieces of evidence during a certification process.

## 7 Barriers to the material use of biomass

Work Package 7 investigates why material use of biomass has developed so sluggishly over the last decade in comparison to energy use. Although various policy documents have stressed that material use is the priority, in reality energy use has enjoyed rapid growth for over 10 years now, while material use of biomass has stagnated.

Figure 7 shows the evolution of the land area devoted to material and energy use in Germany since 1994. Although the area of land given over to material use was initially greater than that for energy use, the comprehensive support system for energy use resulted in a tenfold growth<sup>3</sup> in its land coverage, whereas material use remained almost unchanged. Which factors caused material use to stagnate despite political backing and considerable R&D funding?

Figure 7: Cumulative land areas for material use and energy use in Germany

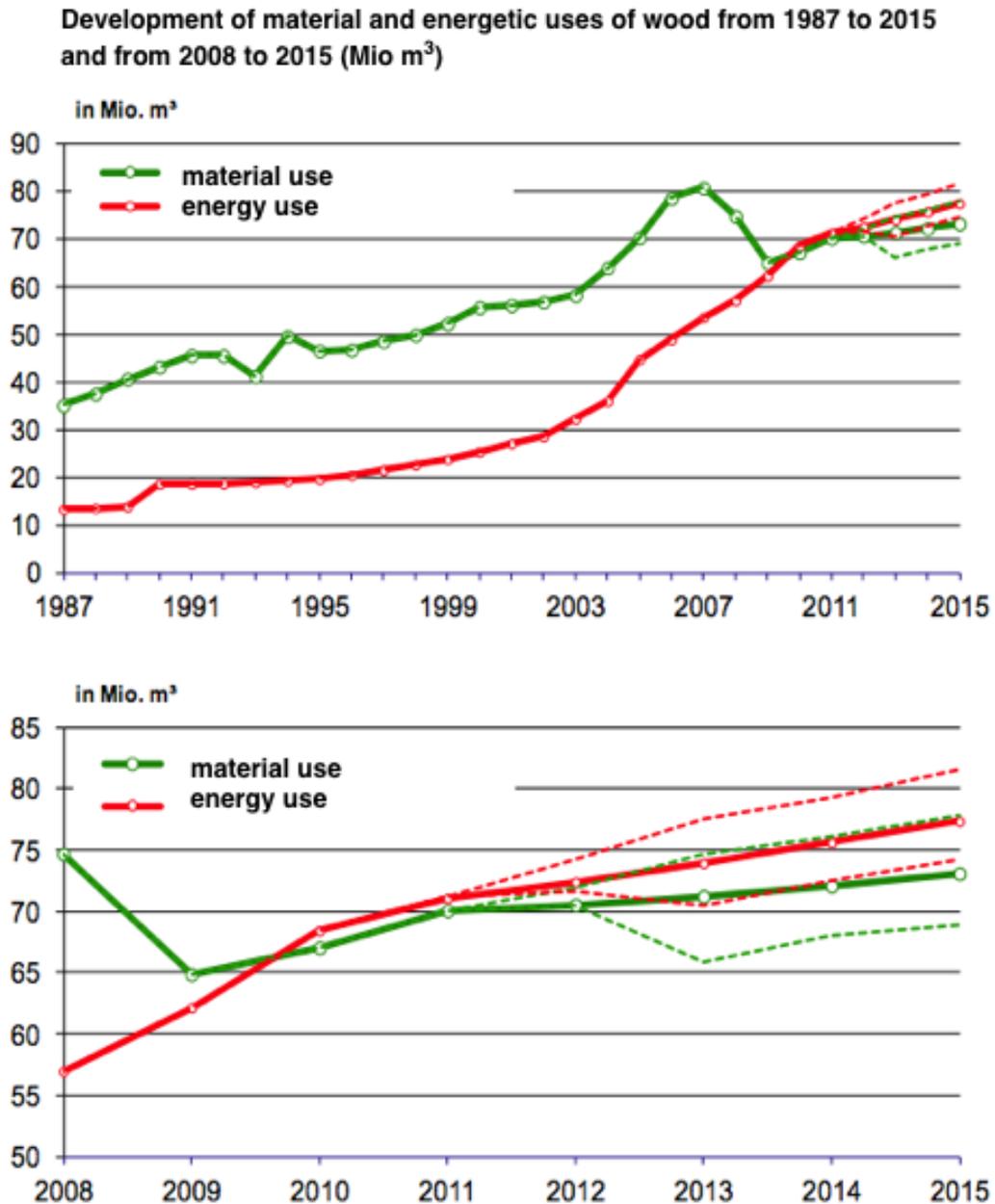


FNR 2012

Figure 8 shows that utilization of wood also shifted to energy use. In 2010 the use of wood for energy surpassed its use as a material for the first time in the history of wood utilization in Germany.

<sup>3</sup> Set-aside land was used at first, but later land was taken out of grain, potato (Lower Saxony) and secondary crops, and pastureland was also converted.

Figure 8: Use of wood for materials and for energy, 1987-2015 and 2008-2015



Mantau 2012

Our research work is based on the premise that the following criteria ought to determine biomass allocation between the different sectors (on the condition that food security is obviously the first priority):

- Maximum resource efficiency and conservation of fossil resources,
- Maximum avoidance of greenhouse gas emissions,
- Maximum added value,
- Maximum employment effects,

- Maximum innovation effects,
- Low substitutability by other renewable resources (sun, wind),
- Minimal state subsidies to achieve economic viability.

Material use leads on just about every one of these aspects, with the exception of avoiding greenhouse gas emissions, where there is little difference between energy and material use from biomass.

The contradiction is clear: although material use of biomass has many advantages over energy use, it has been stagnating for decades while energy has experienced great expansion. This was a point of departure for analyzing the framework conditions for use - there must be specific obstacles and barriers preventing the development of material use, for otherwise this discrepancy is hard to explain.

The analysis of obstacles did indeed come to the conclusion that there is an extensive nexus of barriers hindering the development of industrial materials from biomass. We have identified about 50 separate obstacles in a multitude of different areas. These range from agricultural, energy, climate, tax and revenue policy to further legal regulations, science and technological development, information, communications, networks, funding and ecology. The long version of this study examines each of these obstacles in detail.

Table 3: Different support systems for energy and material use in Germany since 2000

Instruments	Biofuels	Biogas for electricity	Wood pellets for electricity or heating	Material use, bio-based products
Tax incentives	Yes	(Yes)	Yes	No
Quotas (biofuels, RED)	Yes	Yes	Yes	No
EEG (electricity/heat)	Yes	Yes	Yes	-
Emissions trading (ETS)	Yes	Yes	Yes	No
Market introduction schemes or special market regulations	Yes	Yes	Yes	Yes (but largely expired) (for lubricants, insulation and bioplastic packaging)
Others (e.g. rural development scheme)	Yes	Yes	Yes	No (CAP reform proposal 2011: Yes)
Research & development	Yes	Yes	Yes	Yes

nova Institute 2013

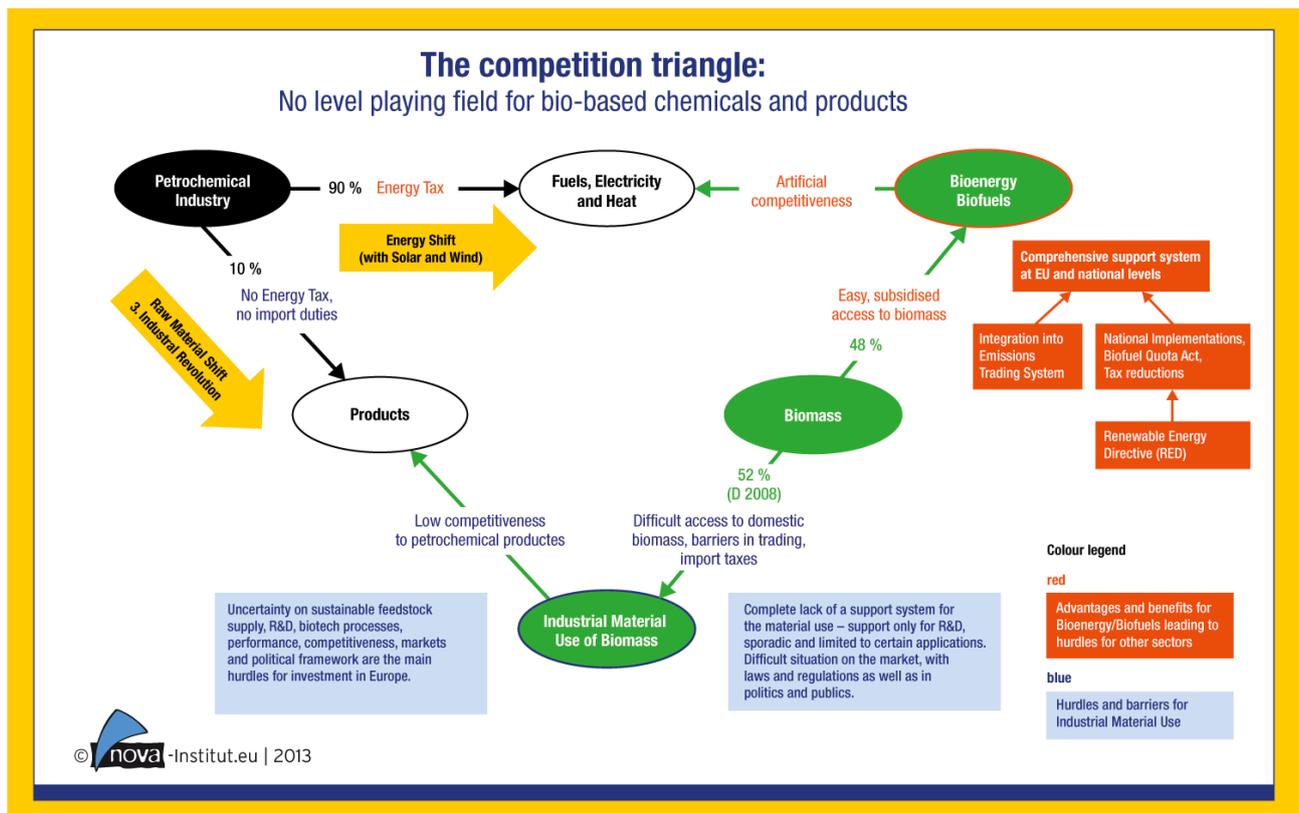
To sum up the results: The existence of a long-standing comprehensive support system for energy from biomass has created a favourable competitive situation compared to fossil energy sources; the latter are also subject to a hefty energy tax. Bioenergy has been rendered artificially competitive by means of favourable political framework conditions.

Material use is competing with bioenergy for biomass that is not used for food or feed. As a result of the comprehensive support system for bioenergy and biofuels, which was ultimately created by the EU RED, the prices for biomass and land have greatly increased. This makes access to biomass for material use much harder and more expensive, but this is not compensated for by support measures. This market distortion hinders the competitiveness of producers of materials from biomass.

The bio-based chemistry and plastics industries are exposed to full competition from chemical industry products. Without any accompanying measures, new, bio-based industries must be developed that can prove their viability in the face of the well-established and long-optimized mass production of the chemical industry. Then there are high biomass prices resulting from the promotion of energy use, which are not counteracted by taxes on fossil carbon sources as a raw material for the chemical industry. All of this creates an extremely tough competitive environment.

The diagram below presents this state of affairs in the form of a “competition triangle”.

Figure 9: The competition triangle: Petrochemicals - Bioenergy/biofuels - Material use of biomass



## **8 Instruments and measures to overcome the identified barriers and ensure a level playing field for material use**

Work Package 8 develops instruments with the aim of overcoming the identified barriers and the resultant discrimination against material use.

The long version describes the wide range of individual instruments in detail. Several workshops with representatives from industry, associations, organizations and the world of politics sought to prioritize the various instruments that had been presented to them. The proposals are divided into:

- a) Potentially extremely effective measures that are desirable as a way of supporting material use and whose implementation requires further targeted work;
- b) Simple instruments that are desirable from the viewpoint of supporting material use and whose implementation is considered relatively easy;
- c) Desirable instruments whose implementation is probably only realistic in the medium term;
- d) Instruments that are considered undesirable or unrealistic by industry or politicians and should therefore not be pursued.

The first category contains proposals for comprehensive reforms to the Renewable Energy Directive (RED) that were developing during the project. These reform proposals aim firstly to create a level playing field in the competition for resources between energy and material use, which has been severely distorted by the one-sided support system favouring bioenergy/biofuels. This section includes proposals not to account in the RED for biomass and residues that could be sensibly used for materials first and, above all, to avoid “double counting” – or else for the RED to give greater weighting to raw materials from cascading use.

Secondly, the reform proposal adopts the innovative approach of allowing material uses of biomass to fill the existing RED quotas and thus to evolve the RED into a Renewable Energy and Material Directive (REMD). The relevant aspects are discussed in detail in the long version.

The other instrument favoured by the participating experts is the development of a comprehensive communications strategy for bio-based materials. The benefits of bio-based products should be better communicated between companies and to consumers. This involves standardization and appropriate labelling of bio-based products.

The long version includes a list of the main “simple instruments, whose implementation is considered relatively easy”.

## **9 What would be the environmental and economic effects of an increased material use of biomass?**

Work Package 9 aims, by means of various future scenarios, to calculate the environmental and economic benefits that would accrue if the available land for renewable resources were increasingly used for materials instead of energy. Four scenarios are developed and assessed on the basis of the findings of the previous work packages.

The scenarios are based on the assumption that 2.5 million hectares are available for renewable resources in Germany, which reflects the initial situation in 2012. No expansion or reduction in this area is expected between now and 2030. Four scenarios are examined, all of which depend on various stages of implementation of the instruments developed and proposed in Work Package 8 (the percentages refer to the area given over to the cultivation of agricultural raw materials for industrial materials).

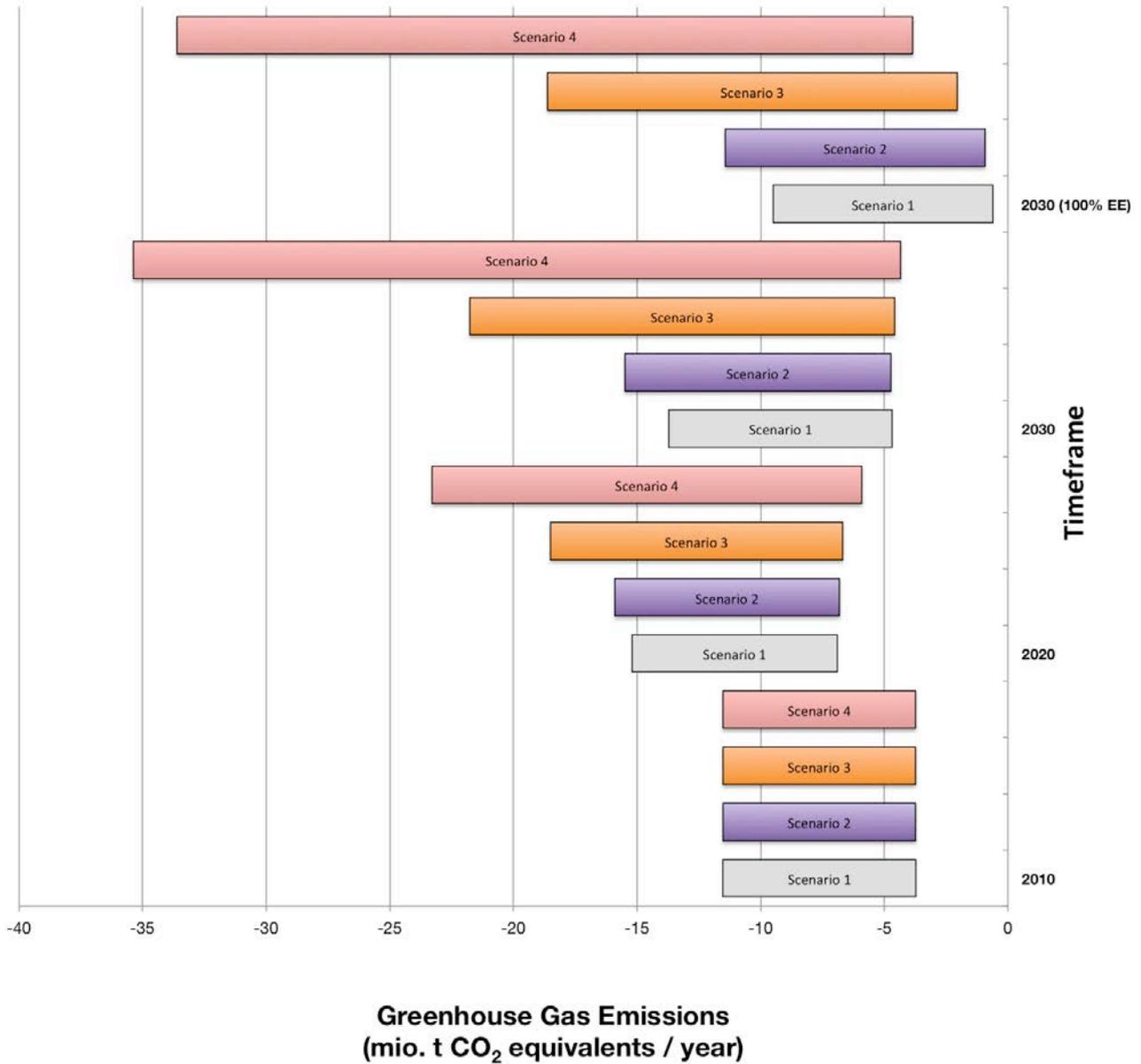
Four scenarios are examined for research into potential development paths:

- Scenario 1 (baseline scenario, 20 % material use by 2030)
- Scenario 2 (25 % material use by 2030)
- Scenario 3 (50 % material use by 2030)
- Scenario 4 (90 % material use by 2030)

Scenario 4 is an extreme scenario and is based on very high growth in all areas. It would require the implementation of virtually all of the proposed instruments. Scenario 4 serves mainly to demonstrate the expected environmental and economic effects if biomass allocation between energy and material usage were to be virtually inverted – from 85:15 today to 10:90 in Scenario 4.

The study calculates and analyzes the environmental effects of the various scenarios in the impact categories of global-warming potential, cumulative energy demand and acidification potential, as well as the macroeconomic figures for added value and employment. The following diagram illustrates the effects on the impact category global-warming potential.

Figure 10: Evolution of greenhouse gas emissions for the years 2010, 2020 and 2030, and for the year 2030 taking account of a 100 % renewable energy scenario



nova-Institut 2013

The effects in three environmental categories (global-warming potential, cumulative fossil energy demand, acidification potential) show wide ranges for the different scenarios resulting from the broad spectrum of different material uses. What emerges very clearly, though, is that the scenarios with a higher proportion of material use also demonstrate the highest potential for reductions or savings. The best material lines achieve significantly greater reductions than those achieved in the field of energy use. This is partly based on the fact that electricity from biomass has fallen behind environmentally with the rising share of solar and wind power (this

is particularly evident in the “2030 (100 % EE)” scenario in Figure 10 when all electricity comes from renewable sources).

Overall, the study comes to the conclusion that material use of renewable resources has the potential to achieve very positive environmental and macroeconomic effects. To fully develop this potential, the share of renewable resources used for materials must be increased, which will only be possible if the political framework conditions are altered. The positive effects in terms of added value and employment associated with increased material use are considerable (the values lie between a factor of 4 and a factor of 10) and are predominantly due to the far longer process and value chains for material use.

Our research findings indicate that a level playing field – or even preferential treatment – for material compared to energy use is called for in order to realize the environmental and macroeconomic potential of material use and to be in a position to make optimal use of limited biomass.

The German federal government has backed the expansion of material biomass use through its action plan for material use from renewable resources and its roadmap for biorefineries. Unlike bioenergy, though, there are neither any quantitative political objectives nor any financial supporting instruments for material use. Despite this lack of a level playing field, the aforementioned reasons (especially security of supply) offer good grounds for thinking that the use of biomass for materials will increase in the future. Should this growth take place in addition to the already extensive energy use of biomass, one must reckon with an increase in the competition for land and raw materials already in evidence today and in the indirect effects associated with this. There is therefore a need for politicians to develop, instead of inadequate *action* plans and goals (separate ones for the bioenergy and bio-based product sectors), a national biomass *allocation* plan or land *allocation* plan, which will ensure a less distorted allocation of biomass between the sectors of demand (industry, the oil and energy economy) and, if necessary, re-define the role of biomass in the energy system and at the same time also take adequate account of other claims on land (e.g. nature conservation).

Until this happens, provisional measures are required. These should in particular include expanding the area- and crop-related sustainability criteria already in force for energy use of biomass as part of the EEG and the Biofuel Quota Act to make them binding for bio-based products as well. For how the biomass for bio-based products is obtained is also decisive for many impact categories and is associated with increased claims on the natural environment. However, there are currently very few possibilities for action and sanctions due to a lack of quantitative political objectives and financial supporting instruments for material use (see above). In our view, voluntary commitment by industry is insufficient.

Our recommendation to political decision-makers is therefore to put an end to the current preferential treatment granted to the use of renewable resources for energy. The concrete measures that we identified as potential instruments in Chapter 8 should be implemented as quickly as possible, from the so-called “simple” measures through to a reform of the EU Renewable Energy Directive.

The greatest environmental effects in the impact categories we studied could be achieved by explicitly orienting the set of supporting instruments towards these environmental effects, independently of whether the biomass is used for materials or energy. This is the only way to fully realize the economic potential of biomass use that is revealed by the full spectrum of different uses.

## 10 Summary

The research project “Environmental Innovation Policy – Greater resource efficiency and climate protection through the sustainable material use of biomass” was commissioned by the Federal Environment Agency (UBA) under the overall control of nova-Institut GmbH in cooperation with Institute for Energy and Environmental Research Heidelberg GmbH (IFEU), FiFo Institute for Public Economies at the University of Cologne (FiFo) and the Öko-Institut e.V. and was carried out from 2010 and 2013.

The question at the heart of the project was: What are the environmental and economic effects of greater material use of biomass, and how can this contribute to the German federal government’s resource and climate protection objectives? This guided our work to identify suitable value chains, to develop a sustainability assessment methodology and to put forward and test proposals for the creation of political framework conditions and instruments to promote the sustainable and efficient use of renewable resources.

The project results give a comprehensive overview of the state of material use in Germany and Europe. First, there is a detailed analysis of the biomass flows for material use. The life-cycle assessment results demonstrate that bio-based products have their advantages and disadvantages, and as such show many parallels to the use of biomass for energy. Assessments of life-cycle analyses of selected lines of biomass use for materials come to the conclusion that material use of biomass is at least equal to energy use. When there is cascading use of the raw material (first for material – as many times as possible – and finally for energy) then material use is far superior to energy use.

An economic assessment of material use also shows distinctly better results than energy use of biomass in terms of added value and employment. In addition, the project proposes a sustainability assessment system for material use that could test and prove the economic and environmental benefits.

Comprehensive analysis of the obstacles shows that despite these advantages, there are over 50 barriers to the development of material use. Some instruments are being developed and put forward to overcome these barriers and they are being discussed and prioritized with a broad group of actors from industry, trade associations, organizations and the world of politics.

The concluding scenarios show that greater material use of renewable resources in Germany would have considerable environmental and economic potential, always on the assumption that there is no expansion in area. The scenarios are based purely on land hitherto used for energy being replaced by material use.

## 10.1 Zusammenfassung

Das Forschungsprojekt „Ökologische Innovationspolitik – Mehr Ressourceneffizienz und Klimaschutz durch nachhaltige stoffliche Nutzungen von Biomasse“ wurde im Auftrag des Umweltbundesamts (UBA) unter Federführung der nova-Institut GmbH in Kooperation mit dem Institut für Energie- und Umweltforschung Heidelberg GmbH (IFEU), dem Finanzwissenschaftlichen Forschungsinstitut an der Universität zu Köln (FiFo) und dem Öko-Institut e.V. von 2010 bis 2013 durchgeführt.

Die zentrale Fragestellung des Projekts war: Welche ökologischen und ökonomischen Effekte hätte eine verstärkte stoffliche Nutzung von Biomasse und wie kann sie zu den Ressourcen- und Klimaschutzziele der Bundesregierung beitragen? Dafür sollten besonders geeignete Wertschöpfungsketten identifiziert, eine Methodik zur Nachhaltigkeitsbewertung entwickelt sowie Vorschläge für die Gestaltung von politischen Rahmenbedingungen und Instrumenten für eine nachhaltige, ressourcenschonende Nutzung von nachwachsenden Rohstoffen entwickelt und geprüft werden.

Die Projektergebnisse zeichnen ein umfassendes Bild der Situation der stofflichen Nutzung in Deutschland und Europa. Erstmals werden die stofflich genutzten Biomasseströme detailliert analysiert. Die Ökobilanzergebnisse zeigen, dass bio-basierte Produkte sowohl ökologische Vorteile als auch Nachteile und damit viele Parallelen zur energetischen Nutzung von Biomasse aufweisen. Die ökobilanziellen Bewertungen ausgewählter Linien stofflich genutzter Biomassen kommen zu dem Schluss, dass die stoffliche Nutzung von Biomasse gegenüber der energetischen mindestens ebenbürtig ist. Im Falle einer Kaskadennutzung des Rohstoffs (erst stofflich – so oft wie möglich – und am Ende energetisch) ist die stoffliche Nutzung der energetischen weit überlegen.

Auch die ökonomische Bewertung der stofflichen Nutzung zeigt hinsichtlich Wertschöpfung und Beschäftigung deutlich bessere Ergebnisse als die energetische Biomassenutzung. Weiterhin wird im Projekt ein Nachhaltigkeitsbewertungssystem für die stoffliche Nutzung vorgeschlagen, mit dem die ökonomische und die ökologische Vorteilhaftigkeit überprüft und nachgewiesen werden kann.

Eine umfassende Hemmnisanalyse zeigt, dass es trotz dieser Vorteile über fünfzig Barrieren für die Entwicklung der stofflichen Nutzung gibt. Um diese zu überwinden, werden einige Instrumente entwickelt und vorgeschlagen, die mit einer breiten Gruppe von Akteuren aus Industrie, Verbänden, Vereinen und Politik diskutiert und priorisiert wurden.

Die abschließenden Szenarien zeigen, dass eine verstärkte stoffliche Nutzung nachwachsender Rohstoffe in Deutschland erhebliche ökologische und ökonomische Potenziale hätte; dabei wird keine Flächenerweiterung angenommen. Die Szenarien basieren auf einer reinen Substitution der bisher energetisch genutzten Fläche durch stoffliche Nutzung.

## 10.2 Synthese

Le projet de recherche "Politique de l'innovation écologique – pour une utilisation plus efficace des ressources et une meilleure protection climatique grâce à l'utilisation durable de la biomasse à des fins matérielles" a été mené durant la période 2010-2013 pour le compte de l'Agence Fédérale Allemande de l'Environnement (UBA), sous la direction de nova-Institut et la collaboration de l'Institut pour la Recherche Énergétique et Environnementale de Heidelberg (IFEU), de l'Institut de l'Économie Publique de l'Université de Cologne (FiFo) et du Öko-Institut.

La question centrale du projet a été: Quels effets écologiques et économiques entraînerait l'utilisation renforcée de la biomasse à des fins matérielles et comment pourrait-elle contribuer aux objectifs en matière de ressources et de protection climatique établies par le gouvernement fédéral? Il faut pour cela identifier la chaîne de valeur appropriée, développer la méthodologie pour une évaluation de durabilité, ainsi qu'envisager et considérer une série de propositions pour la création d'un cadre politique et des instruments pour l'utilisation durable et efficace des matières premières renouvelables.

Les résultats du projet montrent une vision complète de la situation reliée à l'utilisation à des fins matérielles en Allemagne et en Europe. Pour la première fois, les flux de conversion de la biomasse ont été analysés en détail. Les résultats de l'analyse du cycle de vie (ACV) montrent des avantages écologiques des produits biosourcés, ainsi que des handicaps, présentant des similitudes avec l'utilisation de la biomasse à des fins énergétiques. L'évaluation de l'analyse du cycle de vie sur des lignes sélectionnées de conversion de la biomasse à des fins matérielles conclut que l'utilisation de biomasse à des fins matérielles est au moins équivalente, en termes environnementaux, à son utilisation à des fins énergétiques. En cas d'utilisation en cascade de la matière première (d'abord à des fins matérielles, chaque fois que possible, et enfin à des fins énergétiques) l'alternative d'utilisation matérielle dépasse de loin l'utilisation énergétique.

En plus, l'évaluation économique de l'utilisation de la biomasse à des fins matérielles montre des résultats significativement meilleurs que l'utilisation énergétique de la biomasse en termes de valeur ajoutée et d'emploi. Dans le cadre du projet, a été également proposé un système d'évaluation de durabilité pour l'utilisation à des fins matérielles, afin de détecter le potentiel pour obtenir des avantages économiques et écologiques.

Une analyse approfondie des barrières existantes a révélé que, malgré les avantages susmentionnés, ils existent actuellement plus de cinquante obstacles au développement de l'utilisation de la biomasse à des fins matérielles. Pour surmonter ces obstacles ont été proposés plusieurs instruments, qui ont été discutés, analysés et priorisés par un large groupe d'acteurs liés à l'industrie, à des associations, à des organisations et à la politique.

Les scénarios finaux montrent qu'une utilisation renforcée de matières premières renouvelables à des fins matérielles en Allemagne aurait un potentiel écologique et économique considérable; sans assumer une extension des superficies. Les scénarios sont basés sur un simple remplacement de la superficie utilisée, jusqu'à présent, pour la biomasse à des fins énergétiques par son utilisation à des fins matérielles.

### 10.3 Resumen

El proyecto de investigación „Política de innovación ecológica – Para un uso más eficiente de los recursos y una mayor protección climática a través del uso sostenible de la biomasa con fines materiales“ ha sido llevado a cabo durante el período 2010-2013 por encargo de la Agencia Federal Alemana de Medio Ambiente (UBA), bajo la dirección de nova-Institut y la colaboración del Instituto para la Energía y la Investigación Medioambiental de Heidelberg (IFEU), del Instituto de Economía Pública de la Universidad de Colonia (FiFo) y del Öko-Institut.

La cuestión central del proyecto ha sido: ¿Qué efectos ecológicos y económicos supondría el uso reforzado de la biomasa para fines materiales y cómo podría éste contribuir a los objetivos en materia de recursos y protección climática establecidas por el gobierno federal alemán? Para ello es necesario identificar la cadena de valores adecuada, desarrollar la metodología para una evaluación de sostenibilidad, así como plantear y considerar una serie de propuestas para la creación de un marco político e instrumentos para el uso sostenible y eficiente de materias primas renovables.

Los resultados del proyecto muestran un cuadro completo de la situación del uso con fines materiales en Alemania y en Europa. Por primera vez, los flujos de conversión de la biomasa se han analizado en detalle. Los resultados del análisis del ciclo de vida (ACV) muestran ventajas ecológicas de los productos de base biológica, así como desventajas, presentando similitudes con el aprovechamiento de la biomasa con fines energéticos. La evaluación del análisis de vida sobre líneas seleccionadas de conversión de biomasa con fines materiales concluye que, el uso de biomasa con fines materiales es al menos equivalente, en términos medioambientales, a su uso con fines energéticos. En el caso de utilización en cascada de la materia prima (primero para uso material, siempre que sea posible, y finalmente para uso energético) la alternativa de uso material supera con creces al uso energético.

Además la evaluación económica del uso de biomasa con fines materiales muestra resultados significativamente mejores que el aprovechamiento energético de la biomasa en términos de valor añadido y empleo. En el marco del proyecto también se ha propuesto un sistema de evaluación de sostenibilidad para el uso con fines materiales, con el fin de detectar el potencial para obtener ventajas económicas y ecológicas.

Un análisis exhaustivo de barreras existentes ha revelado que, a pesar de las mencionadas ventajas, existen actualmente más de cincuenta obstáculos al desarrollo del uso de biomasa con fines materiales. Para superar estos impedimentos han sido propuestos varios instrumentos, que han sido discutidos, analizados y priorizados por un amplio grupo de actores vinculados a la industria, asociaciones, organizaciones y a la política.

Los escenarios finales muestran que un uso reforzado de materias primas renovables con fines materiales en Alemania tendría un potencial ecológico y económico considerable; sin asumir extensión de superficies. Los escenarios se basan en una mera sustitución de la superficie utilizada, hasta ahora, para biomasa con fines energéticos por su utilización para fines materiales.

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