The Political Economy of Fostering a Wood-based Bioeconomy in Germany

Die politische Ökonomie der Förderung einer holzbasierten Bioökonomie in Deutschland

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Abstract

To increase the sustainability of economic processes and products as well as the use of sustainable resource inputs, a transition is required from the hitherto predominantly fossil resource-based "throughput economy" towards a circular flow economy based on renewable resources, the so-called bioeconomy. This paper considers the transition challenge from the perspective of dynamic theories on lock-in effects and lock-out options. Within this framework, a successful transition requires a twofold equilibrium: the economic sustainability equilibrium and a corresponding political equilibrium providing the corresponding transition policies. Based on the positive analysis of both current bioeconomy policies and policy demand by bioeconomy actors in Germany, this paper develops recommendations on how a political equilibrium may be achieved which favors a sustainability-oriented transformation to a bioeconomy. One means of doing so, for example, is to combine a gradual development of existing policies with efforts to identify and support innovative niche products and processes.

Key Words

bioeconomy; wood; new political economy; instruments; multiple equilibria; path dependencies; Germany

Zusammenfassung

Zur Erhöhung der Nachhaltigkeit ökonomischer Prozesse und Produkte sowie der Nutzung nachhaltiger Produktionsinputs bedarf es einer Transformation von der derzeitigen fossilen „Durchflussökonomie" hin zu einer Kreislaufwirtschaft basierend auf erneuerbaren Ressourcen, der sogenannten Bioökonomie. Das vorliegende Papier betrachtet die Transformationsherausforderung aus Sicht dynamischer Theorien zu Lock-in-Problemen und Lock-out-Optionen unter Hinzuziehung von Ansätzen zum institutionellen Wandel und Innovationssystemen. Es wird gezeigt, dass zur Transformation ein doppeltes Gleichgewicht vorliegen muss: ein ökonomisches Nachhaltigkeitsgleichgewicht auf abweichendem Entwicklungspfad und ein politisches Gleichgewicht, das die dazu nötigen Transformationspolitiken bereitstellt. Basierend auf der positiven Analyse des gegenwärtigen Angebots an „Bioökonomie-Politiken" und der Nachfrage danach durch relevante Bioökonomie-Akteure in Deutschland werden in diesem Papier Vorschläge ausgearbeitet, wie auch politisch ein neues Gleichgewicht zugunsten von Transformationspolitiken erreicht werden kann, etwa durch graduelle Entwicklung bereits bestehender Politiken sowie die Identifizierung und Förderung innovativer Nischenprodukte und -prozesse.

Schlüsselwörter

Bioökonomie; Holz; Neue Politische Ökonomie; Instrumente; multiple Gleichgewichte; Pfadabhängigkeiten; Deutschland

1 Introduction

Improving the overall sustainability of the economy's supply of goods and services requires a fundamental structural change from the hitherto predominant "throughput economy" based on non-renewable fossil resources towards a circular flow economy based on renewable resources. The concept of a bio-based economy (bioeconomy) is widely considered to fit this new path (RICHARDSON, 2012; STAFFAS et al., 2013; BMEL, 2014a). Bioeconomy is defined as the knowledge-based "production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy" (EC, 2012: 3). From a dynamic modelling perspective, such a transition towards a sustainable bioeconomy may be interpreted as a switch from a fossil-based to a bioeconomy-based equilibrium. However, this path transition is inhibited by several market failures: i) environmental externalities that derive from the use of fossil raw materials that are insufficiently internalized by climate policy and environmental policy (JENKINS, 2014; LAHL, 2014: 61), ii) knowledge spillovers arising partly from innovation activities but also from processes of "learning by doing" when applying technologies, thus leading to underinvestment in innovation and societal learning (FISCHER and NEWELL, 2008; JAFFE et al., 2005), and iii) technological as well as institutional path dependencies which lead to a lock-in into current fossil resource-based structures of production (UNRUH, 2000; 2002).

Due to these path dependencies, market forces are insufficient on their own to create a path transition (see PANNICKE et al., 2015 for a more detailed discussion). For example, an economy can be locked into a fossil equilibrium, widely referred to using the term "carbon lock-in" (UNRUH, 2000; 2002). The question, then, is whether an explicit "bioeconomy policy" can break such a lock-in and, if so, how. Market failures can be tackled by introducing a comprehensive policy mix aimed at initiating a path transition and supporting the creation of an effective innovation system. Such a transition will inevitably be affected by the various competing interests of political stakeholders (politicians, producers, consumers and voters), which would need to be dealt with in political arenas ("policy markets"), and by potential government failures such as information deficits concerning the potential impacts of regulations. In this context the question is which actors have which interests in this transition, and how these different interests, articulated in the "policy markets" for bioeconomy policies, can be coordinated.

Currently there is no "bioeconomy policy", either in Europe or in Germany, for creating a real path transition towards a bio-based economy. Such a policy concept would be clearly defined and based on transition objectives and a set of instruments for transition management. Instead, the current bioeconomy policy is largely based on policy strategy papers as well as research and development (R&D) support for pilot projects such as the German Excellence Cluster "Bio-Economy". At the national level, Germany has a "National Policy Strategy on Bioeconomy" (BMEL, 2014a), an "Action Plan of the Federal Government for the Material Use of Renewable Resources" (BMELV, 2009), a "National Biomass Action Plan" (BMELV/BMU, 2010), a "National Research Strategy: Bioeconomy 2030" (BMBF, 2010) and a "Charta for Timber" (BMVEL, 2004). Similarly, at the EU level the bioeconomy is addressed by the European Union bioeconomy strategy "Innovating for Sustainable Growth: A Bioeconomy for Europe", which contributes significantly to the objectives defined in the Europe 2020 flagship initiatives "Innovation Union" and "A Resource Efficient Europe" (EC, 2012).

The focus of this paper is on woody biomass because interest in non-food feedstocks has increased within the last few years. Not least due to sustainability issues such as the food vs. fuel debate (CARUS and DAMMER, 2013), the focus of bioeconomy-based feedstocks has been expanded to include lignocellulosic raw materials and especially wood (KAJASTE, 2014; LIMAYEM and RICKE, 2012). For instance, the German Excellence Cluster "BioEconomy" specializes in the comprehensive processing of lignocellulosic materials, especially beech wood (BMEL, 2014a: 65). While the conventional use of wood materials (paper, furniture etc.) is predominantly market driven and well established, supply and demand for innovative wood products and wood-based uses still remains low despite political strategies that seek to encourage innovations and their entry into the market. Although bioenergy use is also part of the bioeconomy (see BIOÖKONOMIERAT, 2012), our focus here is on policies that promote material rather than energetic uses of wood because, compared to bioenergy policies, they have received less scholarly attention to date (exceptions are for example MCCORMICK and KAUTTO, 2013, or STAFFAS et al., 2013). For wide-ranging overviews of the challenges arising in the bioenergy policy context, see SRU, 2007; WBA, 2007; WBGU, 2008.

Utilizing insights from the theory of institutional change and the innovation systems approach, we examine what elements an "economically rational bioeconomy policy" would need to comprise. Based additionally on a public choice analysis of actors and their interests, we then focus on two research questions: i) what are the political system requirements needed to initiate a paradigm shift? and ii) can the political system provide appropriate transition and innovation policies, i.e. is the initiation of a genuine path transition even politico-economically feasible? In order to answer these research questions we take a case study approach, as this allows us to gain structural insights into the potential barriers and drivers of transition policies which are also linked to European policies aimed at promoting the bioeconomy. Germany is taken as an example because of the prominent role the bioeconomy has in R&D as well as in political strategies. Given that the groups of actors – and therefore the drivers and barriers – involved can be expected to be similar in other EU and OECD member states, we expect our results to be transferable accordingly.

The paper is structured as follows: first, we outline what we call the wood-based bioeconomy policies that are part of a transition approach (Section 2). Then we discuss the particular relevance as well as the technological and socio-economic potential of a wood-based bioeconomy, illustrating its potential to support a sustainable path transition (Section 3). Section 4 introduces dynamic theories on lock-in challenges and lock-out options. Section 5 outlines the political requirements needed to overcome these lock-in challenges and provides recommendations for a path transition policy approach. Against this background, in Section 6 we discuss whether the German political system might be able to deliver appropriate policies to initiate a path transition and create a more sustainable equilibrium. Section 7 concludes the paper by summarizing its findings.

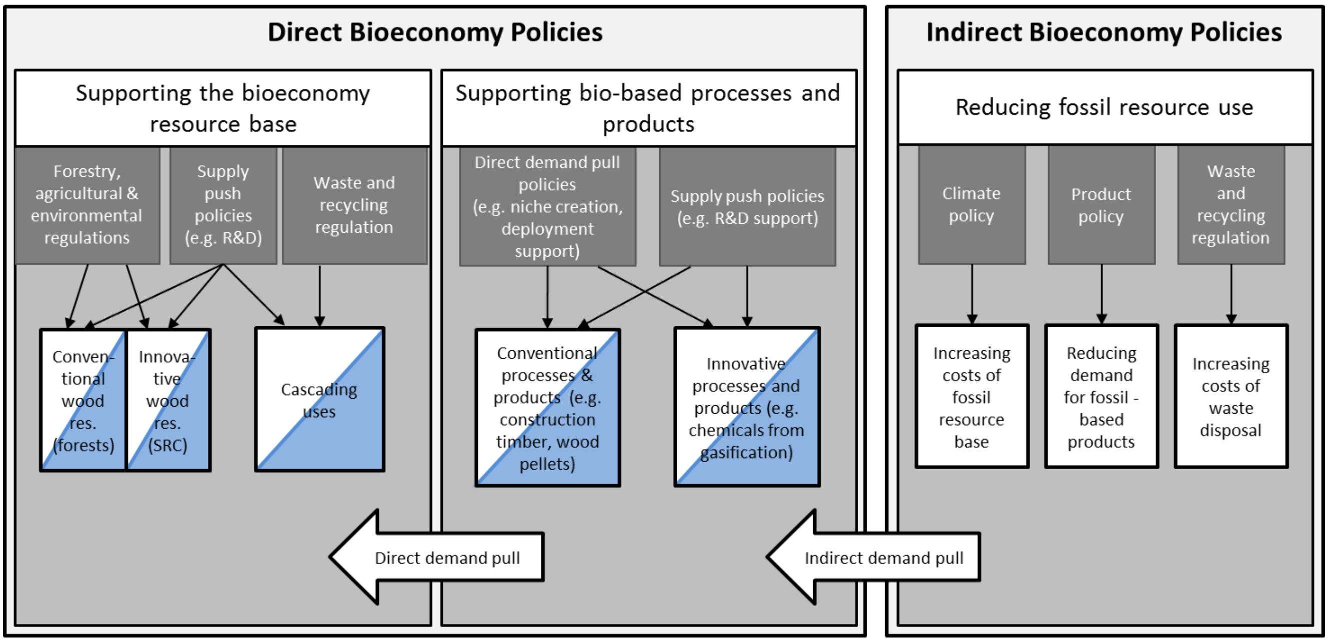
2 Defining Wood-based Bioeconomy Policies

Policies aimed at fostering a wood-based bioeconomy are quite complex and therefore need to be carefully defined first. There is no official term of "bioeconomy policy" or "bioeconomy law" in the EU and Germany (cf. LUDWIG et al., 2015a). Therefore, we differentiate between policies that focus on 1) direct support for the bioeconomy resource base (relating to wood), 2) direct support for wood-based processes and products, and 3) the reduction of fossil resource use. In this way our analysis focuses on policies with both a direct and indirect impact on the wood-based bioeconomy (Figure 1):

1. Direct policies deal with bio-based raw materials, processes and products, either by supporting their supply (for instance by providing funding for innovation efforts) or by creating a direct demand pull (cf. GRUBLER et al., 2012; FOXON et al., 2005). Bio-based products may be new innovative products or substitutes for existing fossil-based products.
2. Indirect policies deal with fossil resources, products and waste, with the aim of reducing overall fossil resource use. This may create an indirect demand pull for bio-based processes, products and resources that can act as substitutes for fossil-based ones.

Two further differentiations seem useful with regard to "direct" bioeconomy policies that address the bio-

Figure 1. Three pillars of wood-based bioeconomy policies



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based value chain (resources and products): (1) quantity-oriented approaches which expand *conventional* uses beyond the current lock-in equilibrium vs. quality/ *innovation*-oriented approaches targeted at new resource harvesting methods or products, and (2) general resource substitution policies vs. bioeconomy policies with explicit sustainability guidelines (blue shading in Figure 1).

3 The Bioeconomy Path: Is there Potential for a Sustainable Wood-based Bioeconomy in Germany?

To frame bioeconomy policies as an approach for a path-transition towards greater overall sustainability is to presuppose that the bioeconomy represents a more sustainable path of socio-economic development than the one we are currently on. Viewed over the long term, Germany possesses considerable technological and socio-economic potential for creating a wood-based bioeconomy (Section 3.1). However, sustainability is not a self-evident outcome from an increased utilization of wood (Section 3.2), so it is necessary to consider concerns over any negative sustainability impacts.

3.1 Potential for a Wood-based Bioeconomy in Germany

First, we need to examine whether there is any significant *technological* potential for substituting fossil resources for wood – over and above existing applications – in order to improve the long-term sustainability of economic processes. Alongside energetic and structural applications, the substances recoverable from wood (i.e. cellulose, hemicellulose and lignin) can be used for material applications (FNR, 2014: 51f.). Besides the conventional use of wood in the building and woodworking industry, cellulose is traditionally used to make paper and pulp as well as regenerated cellulosic fibres such as viscose for clothes or cellophane for food packaging (KLEMM et al., 2005). As a by-product of the pulp and paper industry, lignin is traditionally used for energy applications (KAMM et al., 2006) and as an admixture (GRUBER, 2004). In terms of the energetic applications of wood, the heating sector is traditionally dominant (MANTAU, 2012: 42). In 2014, heat produced from solid bioenergy carriers accounted for 63.9 % of final energy consumption from renewables in the heating sector (covering 6.3 % of total final heat consumption) (cf. BMWI and AGEE-STAT, 2015). In addition to heat production, woody biomass and other types of solid biomass contribute significantly towards generating renewable electricity. Electricity produced from solid bioenergy carriers amounted to 7.4 % of gross renewable electricity production in 2014 (covering 2.1 % of total gross electricity consumption) (ibid.).

Innovative structural applications of wood include the use of shaped wood in cars (WEHSENER et al., 2014: 100; LETTAU-TISCHEL, 2012: 12) and in products where wood shavings are used as an admixture to the material matrix, as in wood-plastic composites (WPC) and concrete (KRIPPNER, 2004; HOMAMI et al., 2013). New cellulose applications are based on the production of chemicals that can be processed further either to become substitutes for fossil-based equivalents such as Bio-PET or to become new bioplastics (ENDRES and SIEBERT-RATHS, 2009).

Lignin is predicted to have significant future technological potential as a feedstock in the production of aromatic chemicals for instance (KAMM et al., 2006; BOZELL et al., 2007), due in part to optimized techniques of biomass conversion such as organosolv pulping, which enable a cleaner separation of substances (PEUKER et al., 2012). The *socio-economic* potential for lignin, however, is not that easy to determine, as it depends on both competitiveness and consumer acceptance. Many biorefinery processes are not competitive yet, with successful commercialization depending on the development of high-value co-products from lignin and hemicelluloses (CHENG and WANG, 2013). Additionally, acceptance of these new products is a prerequisite for commercial success. Bio-based substitutes have to be integrated into existing markets, where equivalent fossil-based products are well established (WYMAN and GOODMAN, 1993). If sustainable production of wood can be guaranteed, its utilization promises several sustainability-related advantages:

1. The use of renewable resources reduces the required amount of material made from non-renewable resources.
2. This in turn can have a positive effect on the climate, because wood-based products tend to be produced with significantly lower greenhouse gas emissions than fossil resource substitutes, and products act as temporary carbon sinks (CHENG and WANG, 2013: 348; BMEL, 2014a).
3. The use and admixture of wood reduces the density and therefore the total weight of materials

(such as concrete) and products (KRIPPNER, 2004: 19f.). This enhances transport efficiency while reducing fuel consumption and CO_2-emissions (KARUS and KAUP, 2001).
4. Resource efficiency can be increased by more fully exploiting resources using innovative technologies and applications (CHENG and WANG, 2013).
5. In some cases, the quality parameters of products can be improved, such as lignin-based bonding agents in chipboards that may be less volatile (GRUBER, 2004).
6. Sustainability can be improved when products are manufactured in a recycling-friendly way, for instance by using environmentally friendly glues and implementing cascade use concepts (GÄRTNER et al., 2013: 18).

The decreasing availability of fossil resources should enhance the relevance of wood as a regenerative chemical raw material and energy source (BMVEL, 2004). However, investments in innovative applications are associated with knowledge spillovers as positive externalities, whereas the environmental benefits of wood use are not fully reflected in market prices (see Section 1). Also, lock-in effects imply that, without political support, a path transition may occur later than is socially optimal (see Section 4).

3.2 The Role of Sustainability Risks

Even if the use of wood can enhance long-term economic sustainability, there are also sustainability risks when fossil resource inputs are substituted for wood. These arise from several conflicts between competing claims on limited resources, as explained in the following:

1. Land use conflicts: Forests and plantations compete with other land uses such as agricultural production and infrastructure. Almost one third of Germany is covered with forests and nearly 60% of the wood used in Germany comes from forests. About 40 % is comprised of miscellaneous wood raw materials, such as materials from landscape conservation, industrial wood residues and waste wood (MANTAU, 2012). Currently short rotation coppices do not account for any significant share (BMEL, 2014c; MANTAU, 2012) and the mobilization of private forests for bioeconomy purposes remains quite low (LUDWIG et al., 2014). Annual timber growth in Germany is about 121.6 million m^3, 75.7 million m^3 of which were used in 2014 (BMEL, 2014c). Wood production is located throughout Germany, though mainly in the south (Bavaria and Baden-Wuerttemberg) as well as in Hesse, Lower Saxony and Brandenburg (BMEL, 2015). The ongoing rise in demand for wood is expected to cause wood imports to increase (cf. MANTAU, 2012), even though the domestic wood supply could be intensified in a sustainable manner, for instance by planting short rotation coppices (cf. STROHM et al., 2012). Given that the economic utilization of natural resources from a given forested area competes with ecological and social requirements such as nature conservation and local recreation and leisure, German forestry management is committed to ensuring the multifunctional use of forests (ENDRES, 2014). However, the potential negative economic, ecological and social impacts of intensified biomass use have also to be considered, especially in relation to imports from countries with low sustainability standards (see for instance LEWANDOWSKI and FAAIJ, 2006; STUPAK et al., 2007; FOLEY, 2005; PANNICKE et al., 2015). More than 80% of raw wood imported to Germany comes from the EU, mainly from eastern and northern Europe as well as from France and Austria (BMEL, 2015: 29f.). However, wood from eastern Europe is sometimes suspected of coming from illegal logging (WWF, 2008: 50).
2. Allocation conflicts: Various applications compete for wood at the processing stage. Its energetic use has grown rapidly within the last 15 years whereas material applications have increased only slightly (MANTAU, 2012). Increasing efforts are underway to facilitate the use of lignocellulosic residues and waste such as straw, pits and parings in order to tackle this competing demand for feedstocks (BMEL, 2014a).
3. Processing route conflicts: several different procedures and technologies compete within the different processing routes and can differ in their environmental impacts. For instance, old production processes for vanillin and viscose are associated with environmental pollution (HOCKING, 1997; KLEMM et al., 2005). New processes have been developed to reduce negative environmental impacts (KLEMM et al., 2005).
4. Product conflicts: new wood products are in direct competition with conventional products whose compliance with health and safety standards has been proven. Because some wood products and regenerated fibres are easily flammable,

additional safety requirements need to be established and met (BYCHKOVA and PANOVA, 2014).

Just as the material utilization of wood is not sustainable per se, the increasing use of renewable resources for energetic applications in Europe raises significant sustainability concerns (EKARDT et al., 2009; ISERMEYER and ZIMMER, 2006). These include the competition for land with food and feed production (HARVEY and PILGRIM, 2011), indirect land use changes (GAWEL and LUDWIG, 2011), and the overexploitation of natural resources (RICHARDSON, 2012: 293; SHEPPARD et al., 2011). Certain sustainability standards and minimum requirements exist but these do not cover all renewable resources and uses (SCARLAT and DALLEMAND, 2011). A level playing field for the various utilization paths of renewable resources would require an extension of minimum sustainability requirements to other resources and applications (CARUS et al., 2011; LAHL, 2014: 62). Given these sustainability risks, a transition to a circular flow economy needs to be complemented by alternative technologies which can reduce the pressure on biomass as an energy and material source. Such technologies may include Power to Gas and Power to Liquid, which derive hydrogen, methane and liquid hydrocarbons from water, CO_2 and surplus energy and which can be used, for instance, in fuel cells and in the chemical industry (cf. GAHLEITNER, 2013). Additionally, however, the possibility of carbon leakage – that is, an increase of emissions in other countries resulting from domestic bioeconomy policies – must be taken into consideration so as to ensure actual climate benefits (cf. MOISEYEV et al., 2014).

4 Lock-in Effects and Institutional Change – a Dynamic Model for Transition Policies

If the fossil-based economy is characterized by path dependencies and positive feedback effects, a non-linear switch needs to be triggered from the fossil equilibrium to a sustainable bio-economy equilibrium. The literature already contains various non-linear transition models such as for communication networks (ROHLFS, 1974) or agroecosystems (PERRINGS and STERN, 2000). What all these "critical mass models involve is some activity that is self-sustaining once the measure of that activity passes a certain minimum level" (SCHELLING, 1978: 95). In the following, we will look at one particular model for the renewable energy sector which simultaneously captures the important characteristics of the bioeconomy case considered in this paper.

SCHMIDT and MARSCHINSKI (2009) modelled the transition from a fossil energy sector to a renewable energy sector. The crucial feature of their model is the possibility of multiple equilibria combined with a coordination problem in selecting the optimal equilibrium. While a social planner would select the high-renewables equilibrium for the near future, the pure market solution without policy intervention gives rise to market failure in that market participants fall back to the low-renewables equilibrium: they fail collectively to bring about the high-renewables equilibrium.

We can frame the transition to a bioeconomy in terms of this dynamic model. That is, we select the most important elements of SCHMIDT and MARSCHINSKI's (2009) model for illustrative purposes, re-labelling them according to the bioeconomy case. Our modified model is based on the following assumptions (among others):

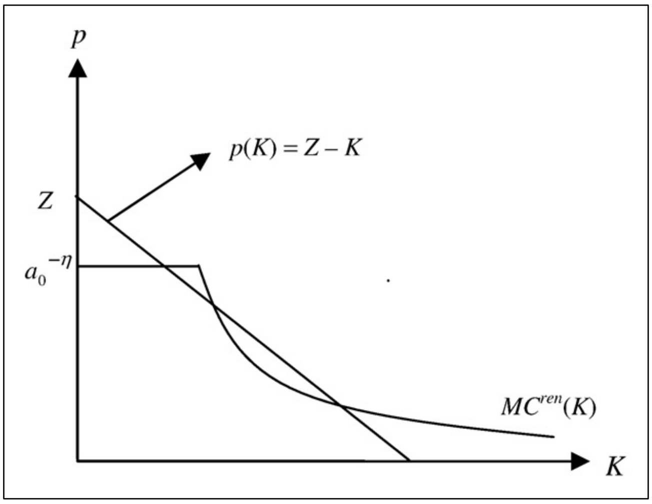
1. It is a two-good economy composed of fossil fuel products and bioeconomy products;
2. The output of bioeconomy products K depends on the prevailing knowledge base a which, in turn, depends on investments in R&D r;
3. The cost function for K is linear if K is small (constant returns to scale); it is concave if K rises above the level where R&D becomes profitable because all units K benefit from R&D (increasing returns to scale);
4. The inverse demand curve for bioeconomy products is defined by $p(K) = Z - K$, where Z is a demand parameter that formally represents excess demand at a price of zero.

It can be shown that under these conditions multiple equilibria may arise and, due to lack of coordination, market participants fail to select the bioeconomy equilibrium even though it would be efficient.

Figure 2 depicts the marginal cost function of the bioeconomy sector $MC^{ren}(K)$[1] and the demand curve. There are three intersection points. The left intersection point corresponds to a situation where no R&D in the bioeconomy sector takes place ("fossil equilibrium" or "lower state"). At the intermediate intersection some R&D occurs in the bioeconomy sector. However, this intermediate point is not a stable equilibrium because a rise in K would imply that

[1] The axis intercept $a_0^{-\eta}$ represents the knowledge base in the bioeconomy sector without R&D. The superscript η is the elasticity of the productivity of knowledge.

Figure 2. Marginal cost function of the bioeconomy and demand curve



Source: adapted from SCHMIDT and MARSCHINSKI (2009: 439)

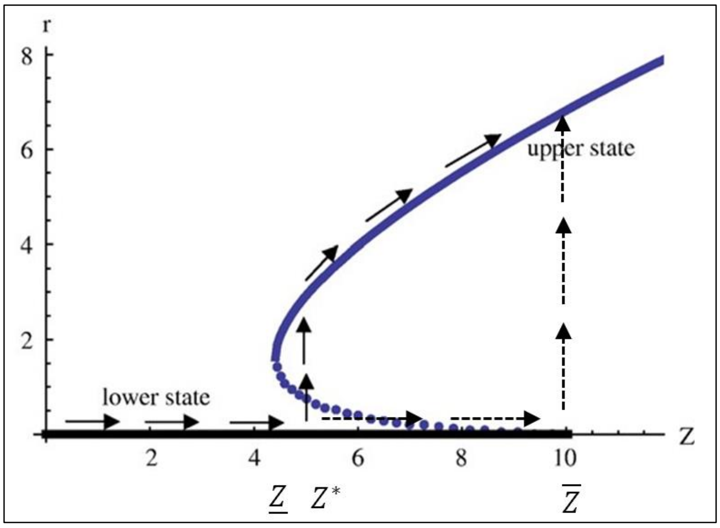
$p(K) > MC^{ren}(K)$ and the bioeconomy output could be further increased. The right intersection point corresponds to a "bioeconomy equilibrium" or "upper state" where there is a self-sustaining bioeconomy sector. Thus, the sustainability problem is how to get from the lower to the upper state. SCHMIDT and MARSCHINSKI (2009) demonstrate that, for a sufficiently high *Z*, a social planner would always choose the bioeconomy equilibrium. Without social planner, the transition to the bioeconomy occurs much later. In terms of the model, both equilibria may coexist for a range of parameter values. Path dependency determines which equilibrium materializes. This path dependency implies that the transition from a lower state to an upper state does not come about by market forces alone.

This can also be seen from Figure 3, a quasi-dynamic diagram which displays the optimal level of R&D in bio-based products *r* for a given level of energy demand: the solid arrows represent the hypothetical social planner's choices of *r* for continuously increasing values of *Z*. For low energy demand $Z < \underline{Z}$, only the fossil equilibrium exists. For $\underline{Z} < Z < \overline{Z}$ both the fossil and the bioeconomy equilibria are stable and the social planner compares both equilibria, selecting that which yields higher overall welfare. Below Z^*, the optimal level of R&D in bioeconomy products is 0. At Z^*, the optimal level of R&D jumps to the upper branch (bioeconomy equilibrium). However, without a social planner or collective coordination, the market participants continuously rely on fossil fuels with only scant or no investments in bioeconomy research. That is, market failure prevails and the economy rests in the fossil equilibrium. In this case, the switch to the bioeconomy equilibrium occurs only when the fossil equilibrium ceases to exist at $\overline{Z}$ (dashed arrows), for instance because fossil fuels are exhausted.

Thus, the model illustrates a lock-in into unsustainable practices, which greatly delays the transition to a bioeconomy, making it more costly as well: the failure of the market to select the "bioeconomy equilibrium" at an early stage entails higher costs of the transition when it finally occurs. Therefore, "on pure cost-efficiency grounds, a stronger policy intervention may be justified" (SCHMIDT and MARSCHINSKI, 2009: 442).

What options do policy makers have when seeking to overcome such lock-in effects? Within the model, a sufficiently high tax on fossil resources would adequately address the market failure. Introducing a fossil resource tax alters the demand function for bioeconomy products to $p = (Z + \tau) - K$. In Figure 2, the fossil resource tax translates into an upward shift of the demand curve, and in Figure 3 it corresponds to a movement along the Z-axis (see Section 6.2.3 for an analysis of pertinent taxes in Germany). If the tax is high enough, the fossil equilibrium ceases to exist. This means that the multiplicity of equilibria vanishes – in Figure 2, only the right intersection point remains and in Figure 3 only the upper branch persists – leaving the bioeconomy equilibrium as the only stable equilibrium.

Figure 3. Transition from a fossil to a bioeconomy equilibrium, with and without social planner



Source: adapted from SCHMIDT and MARSCHINSKI (2009: 439)

5 Policy Implications of the Dynamic Model: What are the Political Requirements for the Transition towards a New Path?

The politico-economic origin of the policy framework renders the introduction of policies sufficiently strong to trigger the non-linear transitions illustrated in Section 4 highly challenging. This makes it necessary to introduce a genuine *political market* framework (KEOHANE et al., 1998). In such a market, supply and demand for (transition) policies converge. Politicians can be considered to act as transfer brokers (MCCORMICK and TOLLISON, 1981) between different interest groups and voters. Strategic coalitions, competition among pressure groups and log rolling characterize this process of balancing interests (BECKER, 1983; ORCHARD and STRETTON, 1997). The political market is in equilibrium when the demand for particular regulatory instruments meets the supply from legislators. What exactly drives demand and supply for policies? Demand for regulation is determined by those interest groups that organize best (STIGLER, 1971), whereas regulation is also influenced by the ideological motives of regulators (PELTZMAN, 1976; KALT and ZUPAN, 1984). With a carbon lock-in in place, the current policy framework can be seen as a representation of the bargaining power of those fossil resource interest groups that oppose the transition towards a bioeconomy (cf. BROUSSEAU et al., 2011).

Against this background, which routes for institutional change are conceivable (cf. NORTH, 1990; NORTH, 1995)? Which policy interventions, sufficiently strong to trigger a sustainable bioeconomy transition, are available? Several factors may be highlighted. Firstly, in order to prepare for an economy-wide transition, support for technological and institutional innovations in smaller niches may be advisable (KEMP et al., 1998). Secondly, policy change may be more feasible if implemented in a gradual, evolutionary way (DEWATRIPOINT and ROLAND, 1995; WEI, 1997; RING, 2007; VAN DEN BERGH and KALLIS, 2013) – that is, while the technological transition towards a bioeconomy might be described as a nonlinear one, the policy interventions required to activate it are gradual. For instance, the ongoing regime shift in Germany's electricity system towards renewable energies is a result of a gradual and eventually self-sustaining interplay between policy interventions, interests and ideas/ideologies rather than a single, drastic policy intervention (STRUNZ, 2014). Thirdly, a "focusing event" (UNRUH, 2002) might be needed to ensure that policy interventions do not gradually peter out but instead accumulate such that the sustainability threshold can be crossed and fossil lock-in averted. Fourthly, in designing policy interventions for sustainability, one important element to be considered is that of transaction costs. Specifically, it has been recommended that policy instruments should be sequenced appropriately, for instance by adapting existing policy frameworks rather than trying to implement radically new instruments from the outset (MCCANN, 2013).

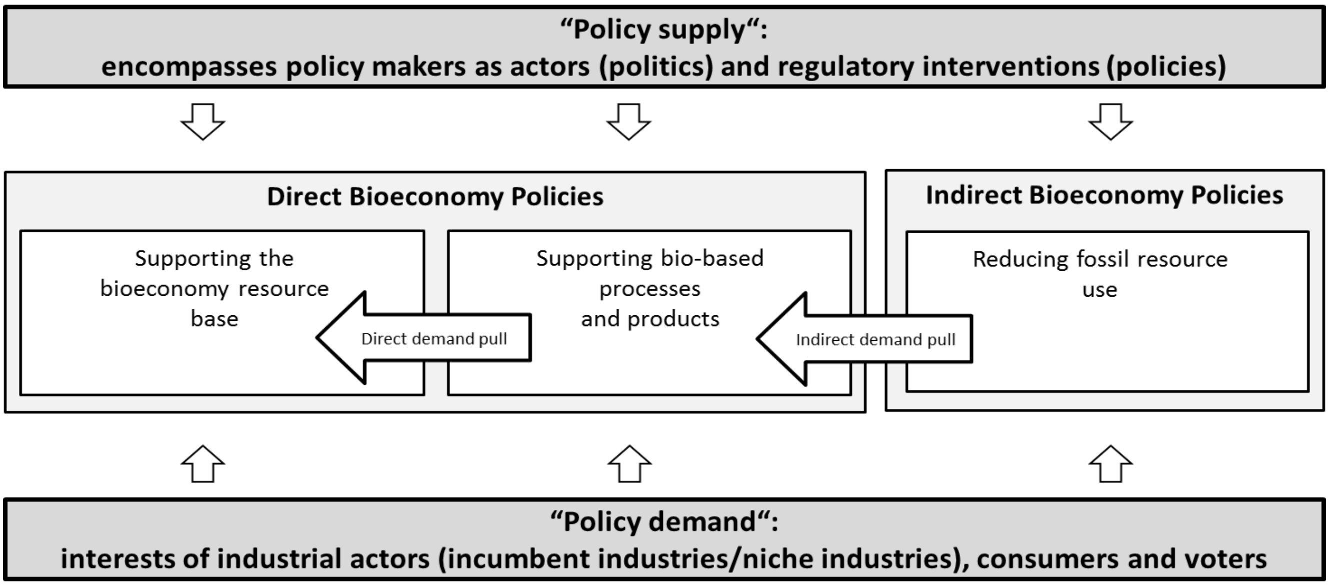
6 The Political Economy of the Wood-based Bioeconomy: The Market for Transition Policies

6.1 The Theoretical Framework

In the following, we explore whether the current political system is able to provide appropriate policy approaches (i.e. instruments) for initiating a transition towards a wood-based bioeconomy as described in Sections 4 and 5. A transition towards a bioeconomy equilibrium requires the existence not only of an economic upper-state equilibrium (in terms of technological feasibility and economic efficiency) but also of a suitable policy pathway that facilitates policy learning and dynamic adaptation. Thus, a simultaneous twofold equilibrium is needed for transition policies. In other words, the "market for policies" in its political equilibrium needs to provide a policy output that actually triggers the transition towards an upper-state equilibrium. This implies that demand and supply for bioeconomy policies match at a sufficiently high level, including dynamic policies that support the bioeconomy resource base and bio-based processes and products, as well as policies that discourage the use of fossil resources (Figure 4).

Following the "market for policies" framework outlined above (MCCORMICK and TOLLISON, 1981; KEOHANE et al., 1998), politicians supply regulatory output according to the relevant interest groups' demand (STIGLER, 1971) while also considering their own ideological motivations (PELTZMAN, 1976; KALT and ZUPAN, 1984). Thus, one prerequisite for a policy pathway that triggers the transition is a sufficiently high level of demand for regulation that increases the availability of wood resources, facilitates the development and diffusion of bio-based processes and products, and induces substitution away from fossil re-

Figure 4. The market for bioeconomy policies



Source: authors

sources. If demand for such regulation is lacking, there may well be an equilibrium on the "market for policies" – but one that merely perpetuates the fossil resource-based economy. A switch to the bioeconomy equilibrium occurs only if demand for appropriate regulation is strong enough.

The following sections analyze the market for wood-based bioeconomy policies from the supply and demand side. In supporting wood-based bioeconomy products and technologies, policies can be distinguished according to two dimensions: i) the focus of policies may lie either on supporting innovative wood resources, technologies and products, or on supporting conventional ones already established in the market (cf. Fig. 1); ii) polices may focus on pathways identified as particularly "sustainable" or, alternatively, they may not make such provisions. Based on an overview of existing policies, we assess whether the current policy supply provides sufficient momentum to initiate a long-term transition away from the fossil fuel-based economy (6.2). We then examine whether there is demand for a higher regulatory output in support of the wood-based bioeconomy (6.3). Based on this analysis, we discuss whether the transition towards a bioeconomy equilibrium is supported by the policy market in the German case and, if not, what possible strategies are available to overcome a lock-in situation (6.4).

6.2 Supply of Wood-based Bioeconomy Policies in Germany

As discussed in Section 2, policies for supporting the bioeconomy transition can encompass indirect policies which reduce the use of fossil resources as well as direct policies which support the bioeconomy resource base and bio-based processes and products. A coordinated policy mix combining supply push and demand pull measures is required to successfully promote a transition process (GRUBLER et al., 2012; FOXON et al., 2005). Currently, important drivers of the German bioeconomy include strategies relating to climate change (e.g. the Climate Action Programme 2020 (BMUB, 2014) and the Energy Concept (BMWI and BMU, 2010)), sustainability (e.g. German Sustainability Strategy (GERMAN FEDERAL GOVERNMENT, 2002)), and innovation (e.g. German High Tech Strategy (BMBF, 2014b)), all of which are aimed specifically at reducing fossil resource use and fostering sustainability in general. Such policies (see Table 1) are generally supported politically by consumers and voters who are aware of sustainability issues and by parts of the business community that see prospects for profit making in the medium and long term.

6.2.1 Policies Supporting the Wood-based Bioeconomy Resource Base

Conventional wood production in forests is influenced mainly by the German National Forest Act and the Federal Forest Acts, which establish sustainability as a guiding principle. The sustainability of wood imports is regulated by a German law aimed at safeguarding the timber trade (HOLZHANDELS-SICHERUNGS-GESETZ, 2011), transposing into national law the EU Action Plan for Forest Law Enforcement Governance and Trade (EC 2173/2005; EC 1024/2008) as well as the European Union Timber Regulation (EC 995/2010).

Financial support for projects that enhance the production and provision of wood is provided, for example, by the German Joint Task for the Improvement of Agricultural Structures and Coastal Protection (GAK) (BMEL, 2014b) and agri-environmental schemes, which form part of the EU's Common Agricultural Policy (CAP) and are co-funded and implemented by the Federal States (see for instance RL AuW/2007). Afforestation measures are an example of the projects receiving support (BMEL, 2014b). Innovative wood production in short rotation coppices can be supported under the CAP's greening pillar, provided that no mineral fertilizer and pesticides are used (MICHALK, 2015). No special sustainability requirements are defined for securing GAK support for short rotation coppices (BMEL, 2014b). Given uncertainties about import price developments and import sustainability, the German Forest Strategy 2020 emphasizes that the availability of domestic wood resources (including timber, residuals, wood from short rotation coppices and residuals) needs to be increased further, along with resource use efficiency improvements (BMELV, 2011). Perspectively, resource supply could be influenced by regulatory support for cascade use concepts through incentives, the amendment of waste charges, or recycling regulation (cf. LUDWIG et al., 2014). However, such regulations would imply additional costs either for the state or market actors. As a result, they can be expected to manifest only when there is sufficient policy demand.

6.2.2 Policies Supporting Bio-based Products and Processes

Many sectoral policies influence bio-based products and processes such as the Construction Products Regulation (EC 305/2011) and the German Energy Saving Ordinance (EnEV), which brings advantages for wood constructions in new buildings (BMVEL, 2004). The German Directive for the Procurement of Wood promotes the use of conventional wood products in public procurement, but wood sources must be verified as sustainable (GERMAN FEDERAL GOVERNMENT, 2011). However, based on the low uptake of bio-based products it can be concluded that the procurement law has not yet led to a significant increase in demand. The reasons for this may include the voluntary nature of the law's provisions to include environmental or social aspects, an alleged disproportional increase in the complicatedness of the associated public tendering process as well as information deficits (LUDWIG et al., 2014). Indeed, LUDWIG et al. (2014) question the law's ability to provide sufficient momentum given the current legal situation, although there might be ways of developing its potential.

Information instruments such as labelling can also promote the use of bio-based products and processes. Up to now, relevant labels have been developed predominately by market actors and non-governmental organizations, for instance environmental product declarations, which are based on international norms (DIN EN ISO 14025:2011-10; DIN EN ISO 14040: 2009-11) as well as on the European DIN EN 15804: 2014-07. Labels such as the Blue Angel eco-label, which is owned by the German Environmental Ministry, offer voluntary sustainability certificates for wood products (BLUE ANGEL, 2015). The aim of international norms and standards for bio-based content (EN 15440) and the recovery of packaging is to support bio-based products without requiring further sustainability certification. Despite labelling, however, demand for bio-based products remains low (cf. WYDRA et al., 2010) – moreover, research indicates that consumers' willingness to pay significant price premiums for "green" product characteristics is limited (CARUS et al., 2014; PACINI et al., 2013; SCHUBERT and BLASCH, 2010).

Incentives for the energetic use of wood without explicit sustainability requirements exist in the electricity sector via feed-in tariffs and feed-in premiums, as well as in the heating sector. Here, relevant instruments include mandatory minimum shares of renewable energy sources (RES) in new buildings, grants and loans for RES-based heating installations, and a reduced value-added tax on firewood. In the transport sector, wood-based biomass-to-liquid applications are supported in principle by means of the biofuels quota, but they are still at the R&D and demonstration stage (NAUMANN et al., 2014: 9). As transport biofuels, these applications would be subject to mandatory sustainability requirements according to the EU Renewable Energy Directive (2009/28/EC).

R&D policies such as cluster promotion (for instance the German Excellence Cluster "BioEconomy" and the Cluster "Forest and Wood")[2] promote innovations and provide incentives for companies to look for substitutes for fossil resources. New technologies are emerging as a result of this, but without effective demand pull measures they are unlikely to overcome carbon lock-in. One exemption to this is the energy sector, where incentives for wood use have proven

2 For further information, see http://www.bioeconomy.de and http://www.cluster-forstholzbayern.de.

highly effective (BRUNS and ADOLF, 2013; THRÄN et al., 2011); discussions about the necessity of introducing binding sustainability requirements at European or national level are still ongoing (EC, 2014; FRITSCHE et al., 2013).

6.2.3 Policies Directed at Reducing Fossil Resource Use

LUDWIG et al. (2015a) refer to climate policies, the chemicals regulation, and the Waste Management Act (Kreislaufwirtschaftsgesetz) as contributing indirectly to fostering the development of a wood-based bioeconomy by reducing fossil resource use. However, existing indirect climate policy instruments, such as the European Emissions Trading System (EU ETS) and taxes on electricity, energy carriers and vehicles focus on reducing fossil fuel use in the energy sector, not in materials sectors (cf. RODI et al., 2011). In the case of the EU ETS, carbon certificate prices have been too low and volatile in recent years to make investments in dedicated biomass plants or even the co-firing of wood in coal power plants profitable (TUERK et al., 2011; KANGAS et al., 2009). Moreover, although the EU ETS favours cost-effective technology choices, incentives for investing in comparatively expensive innovative technologies remain limited due to influences from market failure in technology markets (LEHMANN and GAWEL, 2013). The German energy tax does not apply to wood, therefore increasing its competitiveness to fossil resources (geothermal,

Table 1. Policies relating to the wood-based bioeconomy in Germany (selected issues)

Policy Type		**Policy Focus**		
		Supporting the bioeconomy resource base	**Supporting bio-based processes and products**	**Reducing fossil resource use**
Con-ven-tional	**Policies with sustainability requirements**	- Forestry Law, e.g. German Federal Forest Act; - Financial support for e.g. afforestation, e.g. GAK, agri-environmental schemes; - Trade law for imports, e.g. Timber Trade Safeguarding Act, EU Timber Regulation (EC 995/2010).	- R&D, e.g. Cluster Promotion: Cluster Forest and Wood; - Voluntary eco Labels, e.g. Blue Angel Eco Label, Environmental Product Declarations; - Procurement Law, e.g. Directive for the Procurement of Wood.	
	Policies without sustainability requirements		- Energy Saving Ordinance; - Incentives for energetic wood use in the electricity sector; - Incentives for energetic wood use in the heating sector (mandatory minimum RES shares, grants and loans, reduced VAT on firewood).	- EU Emissions Trading System (electricity sector); - Taxes, e.g. electricity tax, energy taxes for heating and transport fuels; - Grants and loans for energy efficiency investments; - Energy efficiency standards for products and buildings; - Energy labelling for household appliances (EU Energy Labelling Directive); - Waste management act, waste prevention programme.
Inno-vative	**Policies with sustainability requirements**	- Financial support for e.g. short rotation coppices, e.g. under CAP (greening pillar).	- R&D: e.g. Cluster Promotion: Cutting edge cluster BioEconomy; - Incentives, e.g. for Biomass to Liquid through biofuels quota.	
	Policies without sustainability requirements	- Financial support for short rotation coppices, e.g. by GAK; - Support of wood recycling, e.g. recycling regulation.	- Norms and standards, e.g. Bio-based Content (EN 15440); Wood-Polymer Composites (WPC, CEN/TS 15534), Compostability of plastics (EN 14995).	- Chemicals regulation (REACH).

Note on nomenclature: "Conventional": policies relating to conventional wood resources and applications. "Innovative": policies relating to innovative wood resources and applications. "Policies with sustainability requirements": mandatory requirements exist in relation to sustainability claims such as the protection of natural resources. "Policies without sustainability requirements": no mandatory sustainability requirements exist; the sole precondition for constituting "sustainability" is resource substitution. Norms and standards constitute private forms of governance rather than policies, but are included for the sake of completeness.
Source: authors

solar and wind power are likewise not subject to the tax) (GAWEL and PURKUS, 2015); however, as with electricity and vehicle taxes, the energy tax is not closely aligned with the climate impacts of allocation decisions (GAWEL, 2010; GAWEL and PURKUS, 2015). Neither EU ETS nor tax regulations lay down sustainability requirements for wood. Besides incentive-based instruments, indirect climate policies also encompass various command-and-control instruments such as standards for buildings and transport; however, the availability and stringency of measures differs between sectors, and the coordination of instruments needs to be improved (cf. RODI et al., 2011).

The aim of the chemicals regulation REACH (EC 1907/2006) is to promote the substitution of hazardous substances in production processes with less hazardous ones in order to reduce harmful impacts on human health and the environment (KÖCK and KERN, 2006). A strict information and control system could lead to a partial abandonment of hazardous substances (LUDWIG et al., 2014). Even though the chemicals regulation may trigger innovation processes, it does not give preference to bio-based substances over substances derived from fossil resources, nor does it include sustainability requirements.

HERRMANN et al. (2012) regard the German Waste Management Act as a powerful instrument to increase the prevention of waste and propose the introduction of a recycling quota of up to 80% in the future. At present this instrument is limited in its effectiveness, as recycling requirements are bound to an assessment of "economic reasonableness" which leaves considerable room for interpretation (HERRMANN et al., 2012; LUDWIG et al., 2015a). To summarize, indirect policies affecting fossil resource uses exist but have so far failed to provide comprehensive incentives to significantly reduce fossil resource inputs in production processes. With the exception of REACH, there are few incentives to adopt innovative material biomass applications; the German Waste Management Act is limited in its effectiveness, and climate policy instruments focus on the energy sector. If, however, indirect instruments would trigger significant demand for wood resources, the lack of sustainability requirements would prove problematic.

6.2.4 How Effective are these Wood-related Bioeconomy Policies?

The analysis of policy supply demonstrates that there are currently a variety of instruments in place that affect the resource base, the products and processes of the wood-based bioeconomy, and fossil resource use. However, so far these instruments have failed to constitute a coordinated policy mix, which in its entirety might provide an impulse for a long-term transition to a bioeconomy equilibrium. Three major problems are apparent:

1. Uncertainty about the resource base: despite selective measures aimed at increasing the bioeconomy resource base, uncertainty about the future availability of innovative and conventional wood resources remains high (HÄNNINEN et al., 2014). Also, there is uncertainty about the effectiveness of governance options for safeguarding the sustainability of large-scale wood imports (UPHAM et al., 2011; COATH and PAPE, 2011). In this context, the promotion of cascading uses proves attractive (BIOÖKONOMIERAT, 2012), but this would require adjustments of the German waste regulation (BAUR, 2013) and is limited by the amount of waste wood available (MANTAU, 2012).
2. Insufficient demand pull for material wood-based products: policies supporting bio-based products and processes are aimed primarily at the R&D stage, but in order to ensure an eventual progression to the market diffusion stage, demand pull measures also need to be in place (cf. GRUBLER et al., 2012; FOXON et al., 2005). Voluntary certification may provide an impetus for conventional bio-based products close to markets, but, given consumers' limited additional willingness to pay for public good characteristics of products, are unlikely to create significant demand for innovative products and processes. Direct policy support measures, meanwhile, are primarily effective when it comes to energetic wood uses – however, this impacts negatively on the availability of resources for material uses (cf. THRÄN et al., 2011). Similarly, indirect climate policy instruments focus on the energy sector. If certificate prices in the EU ETS were to increase sufficiently to make co-firing profitable, it could lead to a significant additional demand for wood. Comprehensive incentives for reducing fossil resource use in material applications could result from adjustments in waste regulation or new climate policy instruments targeted at the materials sector – so far, however, policies are not geared towards significantly reducing fossil resource inputs in production processes, and it is likely that the political costs of such measures would be high.

3. Safeguarding the sustainability of wood-based products: Major uncertainties remain with regard to the sustainability aspects of biomass availability and the environmental impacts of bio-based production (WEISS et al., 2012). The way sustainability requirements are addressed in policies remains selective – if wood demand for energy or material uses increased further, it would be necessary either to take sustainability constraints into account more comprehensively when designing instruments or to "package" them together with a sustainability certification scheme. To avoid distortions and leakage effects, sustainability certification would need to be independent of the end use of wood, and a coordination of standards on the EU level and beyond would be desirable (cf. SCARLAT and DALLEMAND, 2011).

6.3 Demand for Wood-based Bioeconomy Policies in Germany

The analysis above has demonstrated that the German policy framework provides only few incentives for a path transition towards a wood-based bioeconomy. These results might not be surprising if it turns out that there is a significant lack of policy demand that could reward politicians for developing transition-oriented policy programmes.[3] Analyzing the demand side of bioeconomy policies helps in determining whether there might be a demand for transition policies and, if there is, in which policy arena.

The business sector comprises a large group of heterogeneous actors. These include conventional wood-related industries such as timber producers and saw mills as well as the construction, woodwork and paper industries. It is also necessary to consider the production of consumer goods and the chemicals industry, comprising innovative applications such as bio-based chemicals, plastics and materials, detergents, body care products and lubricants (FNR, 2014: 115). This broad range of actors in the wood-based bioeconomy alone is reflected in the variety of their interests as well as their influences. Many actors – especially in the chemical industry – lack interest in transition policies (VCI, 2012; BIOÖKONOMIERAT, 2015).

Moreover, domestic forestry actors have few incentives to support the increasing material use of wood, because high demand from the energy and conventional wood products sectors has already generated favourable market conditions (cf. FNR, 2014: 56). An increase in demand for wood applications might simply serve to increase the amount of imports (cf. MANTAU, 2012), but whether a political lobby exists for such an increase is unclear. At the same time innovative material uses are often not competitive as fossil-based substitutes. An increase in biomass availability is possible, but is currently not being actively pursued.

On the demand side, voters and consumers belong to the key actor groups. Voters' preferences regarding sustainability policies (whether in support of them or in opposition) influence political decision making, because without voters' support the credibility of bio-based policies remains limited. However, voters have reason to prefer environmental and sustainability-oriented policies which do not (at least perceivably) burden them with additional costs (SCHNEIDER and VOLKERT, 1999; HANSJÜRGENS, 2000; GAWEL, 1995). Environmental interest groups or the Green political party could influence public opinion, but they need to become actively engaged in the debate. A few environmental protection organizations are in the process of establishing their positions on the bioeconomy and it can be expected that they will become further engaged as the bioeconomy grows (MCCORMICK, 2011). Currently, the link between the bioeconomy and nature conservation has not been addressed at the European level (OBER, 2015). At the national level civil society is unable to get involved in the issues due to a lack of corresponding structures in the Bioeconomy Council and the relevant government ministries, BMEL and BMBF (FORSCHUNGSWENDE, 2015).

Finally, an expansion of the bioeconomy also gives rise to sustainability risks (see 3.2). So far, consumer awareness of bioeconomy products is rather low; it is not easy to communicate their advantages because they have similar features as fossil-based products but are higher in price (VANDERMEULEN et al., 2012). For the future, different scenarios are possible where voters and consumers either generally support sustainable production or support sustainable products when their prices are not higher compared to conventional products (HAGEMANN et al., in prep.). On the other hand, consumers may raise sustainability concerns, as has been the case with bioenergy and biofuels (cf. PFAU et al., 2014: 1234).

To sum up, the interests of consumers and voters in relation to bio-based production are diverse. The voter market is also heterogeneous as a consequence but tends to be risk-averse with respect to costs. If

[3] By comparison, consider the clear demand for climate mitigation by various actors that contributed to the introduction of the ETS (cf. BRAUN, 2009).

consumers and voters provide little support for policies aimed at transitioning away from the fossil equilibrium, bioeconomy initiatives will peter out, and indeed currently the political conditions for a bioeconomy equilibrium are not yet given. Instead, politicians are resorting to symbolic policies (EDELMANN, 1964; HANSJÜRGENS, 2000): although they state that the transition towards a bioeconomy is desirable, the actual policies they are implementing (such as information dissemination) are insufficient to dislodge the economy from the fossil equilibrium. What a successful transition requires above all are adequate regulations that sanction the use of fossil resources – however, this would generate a political backlash from fossil interest groups.

6.4 Policy Recommendations to Overcome Lock-in Situations

Overcoming the current carbon lock-in and switching from the fossil equilibrium to the sustainable bioeconomy equilibrium requires a gradual extension of existing policies. As SÖDERHOLM and LUNDMARK (2009: 15) suggest, these policies have to be carefully specified: "An important policy lesson, however, is not to directly regulate the allocation of forest resources between different sectors or promote a certain industrial structure. The rationale for policy intervention lies instead in identifying situations in which essential societal costs and benefits do not enter into the private decision-making process."

An indirect demand pull for bioeconomy products and processes can result primarily from a strengthening of climate and recycling policies. However, stringent regulations in climate politics could lead to resistance and thereby paralyze the transformation process. The lack of demand for policies that increase the costs of fossil resource use could therefore constrain the development of the bioeconomy. In addition, such policies would primarily support the use of wood applications with good prospects for competitiveness (such as the energetic use of wood in the heating sector) rather than more expensive innovative approaches. As a result, R&D support and measures designed to create demand for innovative bioeconomy applications are also required as part of the policy mix (cf. GRUBLER et al., 2012; FOXON et al., 2005). The latter in particular may contribute towards the formation of an advocacy coalition for bioeconomy pathways, which may bring about political support for more stringent climate and recycling policies in the long term (LEHMANN et al., 2012).

Labelling and R&D are the current methods of choice (BMEL, 2014a), and are important in terms of increasing the knowledge and acceptance of bio-based processes and products among companies, consumers and voters as well as fostering learning effects. However, experiences from bioenergy sustainability certification (PACINI et al., 2013) and other products with public good characteristics (see SCHUBERT and BLASCH, 2010, for an overview) make it doubtful whether voluntary certification alone can create a sufficient demand pull to enable the transition from R&D and demonstration stages to market diffusion. Potentially, consumers' willingness to pay for bio-based products could increase if products combined credible environmental benefits with quality advantages over fossil fuel-based products (SCHUBERT and BLASCH, 2010).

Enhanced "green public procurement" may be a further strategy for supporting niche creation. When designing direct demand pull instruments, a trade-off emerges in that a critical mass is required to increase profitability. However, if policy-induced increases in the demand for wood are significant, it may lead to inefficiencies caused by a distortion in allocation decisions between alternative resource uses; also, sustainability problems may emerge. For example, safeguarding the sustainability of wood supply can prove problematic, particularly if large-scale imports are required to satisfy demand (UPHAM et al., 2011; COATH and PAPE, 2011). Furthermore, when selecting bioeconomy products or processes for direct support, policy makers are faced with high information requirements regarding a wide variety of alternative options, their impacts, and associated uncertainties (PURKUS et al., 2015). Appropriate alternatives are (preferably in the following temporal order): i) a focus on reforming framework conditions such as climate and waste policies, ii) targeted niche support for innovative technologies and products, and iii) conditions for a market-induced selection of the most sustainable and cost-effective ones from a broad range of bioeconomy products and technologies. Furthermore, a long-term orientation – especially important to investors – has to be an inherent part of policies (DAMMER and CARUS, 2014). Currently, however, there are no signs of this. Whereas the transition in the renewable energy sector has been accompanied by the formation and support of interest groups (LEHMANN et al., 2012), in the bioeconomy it is more difficult to reach a critical mass of supporting interests because these interests are much more heterogeneous.

7 Conclusion

The transition from a fossil-based economy to a bioeconomy is non-linear. Policy interventions are required to overcome path dependencies and lock-in effects in this process. The challenge for "bioeconomy policies" is multi-dimensional: heterogeneous actors require different levers. To overcome lock-in effects, a critical threshold towards the bioeconomy needs to be crossed; afterwards, the transition process might be self-sustaining, with bioeconomy technologies essentially becoming a "backstop". Such a critical transition can be prepared, but it cannot be achieved through R&D support alone, which is currently the dominant bioeconomy policy approach when it comes to innovative applications. Complementary policies which directly support niche formation for the wood-based bioeconomy and reduce the use of fossil resources are equally necessary. Policies which result in a large-scale direct demand pull for selected material wood uses, on the other hand, seem less promising, due to associated distortions in wood markets and the high information requirements that policy makers face when designing interventions.

Our analysis has shown that a range of policies currently exists but that the overall effect is insufficient to actually initiate a path transition. From a normative perspective, incentives should be set only in order to overcome market failures. Presently, we conclude that politicians are not inclined to initiate comprehensive path changes due to the low demand for regulation on "policy markets". Rather, the politically rational strategy is to provide symbolic policy answers or to focus on support policies for R&D. On the demand side, actor groups either have no substantial interest in strong bioeconomy policies or are unable to take an effective stance, whereas fossil interest groups are in a position to promote the further use of fossil resources.

Consequently, the wood-based bioeconomy in Germany could be fostered by gradually making existing policies more rigorous – the ones focused directly on biomass and production processes as well as the ones aimed at reducing the use of fossil resources (e.g. strengthening the EU ETS, complementary climate policy instruments for non-ETS sectors) – while communicating a clear long-term commitment to path transition. Additionally, these policies need to be specified further to focus primarily on sustainable production and re-use (e.g. through instruments of the law on circular flow economy removing existing barriers for re-use and waste processing – see LUDWIG et al. (2015b) on HTC processes) and to enhance innovative niche development (e.g. by encouraging the use of sustainably sourced timber products through Green Public Procurement (EU, 2011), including for instance wooden tubes for civil engineering (see SANDBERG et al., 2013: 80ff.)). At the same time, more research is required on the design and implementation of more (cost-) effective waste regulation, as well as on instrumental options for a (cost-) effective climate policy for the materials sector.

References

BAUR, F. (2013): Förder- und Lenkungsinstrumente zur energetischen Nutzung von Biomasse-Reststoffen. Presentation held at 2. IZES-Energie-Kongress: EEG 2.0 im Spannungsfeld von Märkten und Regulierung, 13.03.2013, Saarbrücken, Germany. URL: http://www.izes.de/cms/upload/pdf/EnergieKongress 2013_Baur_Frder-_und_Lenkungsinstrumente.pdf, accessed 27 August 2015.

BECKER, G. (1983): A theory of competition among pressure groups for political influence. In: Quarterly Journal of Economics 98 (3): 371-400.

BIOÖKONOMIERAT (2012): Sustainable use of bioenergy. Recommendations of the BioEconomyCouncil. Forschungs- und Technologierat Bioökonomie (BÖR), Berlin.

– (2015): Die deutsche Chemieindustrie – Wettbewerbsfähigkeit und Bioökonomie. BÖRMEMO 02. Reports of the BioEconomyCouncil. Forschungs- und Technologierat Bioökonomie (BÖR), Berlin.

BLUE ANGEL (2015): URL: https://www.blauer-engel.de/en/our-label-environment, accessed 02.09.2015.

BMBF (German Federal Ministry of Education and Research) (2010): Nationale Forschungsstrategie BioÖkonomie 2030 – Unser Weg zu einer bio-basierten Wirtschaft. Bonn.

– (2014a): Bioökonomie in Deutschland. Bonn.

– (2014b): Die neue Hightech-Strategie – Innovationen für Deutschland. Berlin.

BMEL (German Federal Ministry of Food and Agriculture) (2014a): Nationale Politikstrategie Bioökonomie. Berlin.

– (2014b): Rahmenplan der Gemeinschaftsaufgabe „Verbesserung der Agrarstruktur und des Küstenschutzes" für den Zeitraum 2014 -2017. Bonn.

– (2014c): Der Wald in Deutschland. Ausgewählte Ergebnisse der dritten Bundeswaldinventur. Berlin.

– (2015): Holzmarktbericht 2014. Abschlussergebnisse für die Forst- und Holzwirtschaft des Wirtschaftsjahres 2014. Bonn.

BMELV (German Federal Ministry of Food, Agriculture and Consumer Protection) (2009): Aktionsplan der Bundesregierung zur stofflichen Nutzung nachwachsender Rohstoffe. Berlin.

– (2011): Waldstrategie 2020. Nachhaltige Waldbewirtschaftung – eine gesellschaftliche Chance und Herausforderung. Bonn.

BMELV/BMU (German Federal Ministry of Food, Agriculture and Consumer Protection/German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) (2010): Nationaler Biomasseaktionsplan für Deutschland. Berlin.

BMVEL (German Federal Ministry of Consumer Protection, Agriculture and Food) (2004): Verstärkte Holznutzung: Zugunsten von Klima, Lebensqualität, Innovationen und Arbeitsplätzen (Charta für Holz). Berlin.

BMWI (German Federal Ministry of Economics and Technology) and BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung. Berlin.

BMWI and AGEE-STAT (Working Group on Renewable Energies – Statistics) (2015): Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland. Unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). Excel-Version. URL: http://www.erneuerbare-energien. de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html, accessed 01.09.2015.

BMUB (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety) (2014): The German Government's Climate Action Programme 2020. Cabinet decision of 3 December 2014. Berlin.

BOZELL, J.J., J.E. HOLLADAY, D. JOHNSON and J.F. WHITE (2007): Top Value Added Chemicals From Biomass. Volume II – Results of Screening for Potential Candidates from Biorefinery Lignin. Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL), Richland, Washington.

BRAUN, M. (2009): The evolution of emissions trading in the European Union – The role of policy networks, knowledge and policy entrepreneurs. In: Accounting, Organizations and Society 34 (3-4): 469-487.

BROUSSEAU, E., P. GARROUSTE and E. RAYNAUD (2011): Institutional changes: Alternative theories and consequences for institutional design. In: Journal of Economic Behavior & Organization 79 (1-2): 3-19.

BRUNS, E. and M. ADOLF (2013): Erneuerbare Wärme in Deutschland: Dynamiken und Akteursinteressen bei der Nutzung biogener Festbrennstoffe. In: EnEV aktuell 3/2013: 11-14.

BYCHKOVA, E.V. and L.G. PANOVA (2014): Sorption of Flame Retardant by Viscose Rayon Fiber in Manufacture of Flame-Resistant Fibers. In: Fibre Chemistry 46 (2): 113-117.

CARUS, M., D. CARREZ, H. KAEB, J. RAVENSTIJN and J. VENUS (2011): Level Playing Field for Bio-based Chemistry and Materials. Policy-Paper on Bio-based Economy in the EU (1). nova-Institute, Hürth.

CARUS, M. and L. DAMMER (2013): Food or non-food: Food or Non-Food: Which Agricultural Feedstocks Are Best for Industrial Uses? In: Industrial Biotechnology 9 (4): 171-176.

CARUS, M., A. EDER and J. BECKMANN (2014): Industry Report: GreenPremium Prices Along the Value Chain of Biobased Products. In: Industrial Biotechnology 10 (2).

CHENG, H. and L. WANG (2013): Lignocelluloses Feedstock Biorefinery as Petrorefinery Substitutes. In: Matovic, M.D. (ed.): Biomass Now – Sustainable Growth and Use. URL: http://www.intechopen.com/books/biomass-now-sustainable-growth-and-use/lignocelluloses-feedstock-biorefinery-as-petrorefinery-substitutes, accessed 26 March 2015.

COATH, M. and S. PAPE (2011): Bioenergy: a burning issue. Royal Society for the Protection of Birds (RSPB). URL: http://www.rspb.org.uk/Images/Bioenergy_a_burning_issue_1_tcm9-288702.pdf, accessed 27 August 2015.

DAMMER, L. and M. CARUS (2014): Study on investment climate in biobased industries in the Netherlands. URL: http://bio-based.eu/download/?did=1719&file=0, accessed 31 March 2015.

DEWATRIPONT, M. and G. ROLAND (1995): The design of reform packages under uncertainty. In: The American Economic Review 85 (5): 1207-1223.

DIN EN ISO 14025:2011-10: Environmental labels and declarations – Type III environmental declarations – Principles and procedures (ISO 14025:2006); German and English version EN ISO 14025:2011. 2011-10.

DIN EN ISO 14040:2009-11: Environmental management – Life cycle assessment – Principles and framework (ISO 14040:2006); German and English version EN ISO 14040:2006. 2009-11.

DIN EN 15804:2014-07: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products; German version EN 15804:2012+A1:2013. 2014-07.

EC (European Commission) (2011): Buying Green! A Handbook on Green Public Procurement. Brüssel. URL: http://ec.europa.eu/environment/gpp/pdf/handbook.pdf, accessed 7 September 2015.

– (2012): Innovating for Sustainable Growth: A Bioeconomy for Europe. Brüssel. URL: ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf, accessed 17 March 2015.

– (2014): State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU. Commission staff working document SWD(2014) 259 final. European Commission, Brussels.

EC 1024/2008: Commision Regulation (EC) No 1024/2008 of 17 October 2008 laying down detailed measures for the implementation of Council Regulation (EC) No 2173/2005 on the establishment of a FLEGT licensing scheme for imports of timber into the European Community.

EC 1907/2006: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation , Authorisation and Restriction of Chemicals (REACH), establishing a European Chemiclas Agency, mending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

EC 2173/2005: Council Regulation (EC) No 2173/2005 of 20 December 2005 on the establishment of a FLEGT licensing scheme for imports of timber into the European Community.

EC 305/2011: Regulation (EU) No 305/2011 of the European Parliament and the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EC.

EC 995/2010: Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market.

EDELMAN, M. (1964): The Symbolic Uses of Politics. University of Illinois Press, Urbana.

EKARDT, F., A. SCHMEICHEL and M. HEERING (2009): Europäische und nationale Regulierung der Bioenergie und ihrer ökologisch-sozialen Ambivalenzen. In: Natur und Recht 31 (4): 222-232.

ENDRES, E. (2014): BWaldG – Bundeswaldgesetz – Kommentar. 2. edition. Erich Schmidt Verlag, Berlin.

ENDRES, H.-J. and A. SIEBERT-RATHS (2009): Technische Biopolymere: Rahmenbedingungen, Marktsituation, Herstellung, Aufbau und Eigenschaften. Hanser-Verlag, Hannover.

EnEV: Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieinsparverordnung – EnEV) vom 24. Juli 2007 (BGBl. I S. 1519). Zuletzt geändert durch Art. 1 V v. 18.11.2013 I 3951.

FNR (Fachagentur Nachwachsende Rohstoffe e.V.) (2014): Marktanalyse Nachwachsende Rohstoffe. Schriftenreihe Nachwachsende Rohstoffe (34). Gülzow-Prüzen.

FISCHER, C. and R.G. NEWELL (2008): Environmental and technology policies for climate mitigation. In: Journal of Environmental Economics and Management 55 (2): 142-162.

FOLEY, J. A., R. DEFRIES, G.P. ASNER, C. BARFORD, G. BONAN, S.R. CARPENTER, F.S. CHAPIN, M.T. COE, G.C. DAILY, H.K. GIBBS, J.H. HELKOWSKI, T. HOLLOWAY, E.A. HOWARD, C.J. KUCHARIK, C. MONFREDA, J.A. PATZ, I.C. PRENTICE, N. RAMANKUTTY and P.K. SNYDER (2005): Global consequences of land use. In: Science 309.5734: 570-574.

FORSCHUNGSWENDE (2015): Zivilgesellschaftliche Plattform Forschungswende. Thema Bioökonomie 2030. URL http://www.forschungswende.de/index.php?id=65, accessed 7 September 2015.

FOXON, T.J., R. GROSS, A. CHASE, J. HOWES, A. ARNALL and D. ANDERSON (2005): UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. In: Energy Policy 33 (16): 2123-2137.

FRITSCHE, U., L. IRIARTE, J. DE JONG, E. VAN THUIJL, E. LAMMERS, A. AGOSTINI and N. SCARLAT (2013): Outcome paper: sustainability criteria and indicators for solid bioenergy from forests based on the joint workshops on extending the RED sustainability requirements to solid bioenergy. International Institute for Sustainability Analysis and Strategy (IINAS), NL Agency Ministry of Economic Affairs, Agriculture and Innovation, European Commission Joint Research Centre Institute for Energy and Transport (JRC IET), Darmstadt et al.

GAHLEITNER, G. (2013): Hydrogen from renewable electricity: An international review of power-to-gas pilot plants for stationary applications. In: International Journal of Hydrogen Energy 38 (5): 2039-2061.

GÄRTNER, S., G. HIENZ, H. KELLER and M. MÜLLER-LINDENLAUF (2013): Gesamtökologische Bewertung der Kaskadennutzung von Holz: Umweltauswirkungen stofflicher und energetischer Holznutzungssysteme im Vergleich. IFEU Heidelberg.

GAWEL, E. (1995): Zur Politischen Ökonomie von Umweltabgaben. Walter Eucken Institut Vorträge und Aufsätze 146. Mohr, Tübingen.

– (2010): CO_2-basierte Kfz-Steuer – eine Klimaschutzsteuer? In: Zeitschrift für Umweltrecht (ZUR) 21 (1): 3-8.

GAWEL, E. and G. LUDWIG (2011): The iLUC dilemma: How to deal with indirect land use changes when governing energy crops? In: Land Use Policy 28 (4): 846-856.

GAWEL, E. and A. PURKUS (2015). Die Rolle von Energie- und Strombesteuerung im Kontext der Energiewende. In: Zeitschrift für Energiewirtschaft 39 (2): 77-103.

GERMAN FEDERAL GOVERNMENT (2002): German Sustainability Strategy: Perspektiven für Deutschland – Unsere Strategie für eine nachhaltige Entwicklung. Berlin.

– (2011): Gemeinsamer Erlass zur Beschaffung von Holzprodukten; Regelung gilt ab 17. Januar 2011 (Verkündung im Gemeinsamen Ministerialblatt). URL: http://www.bmel.de/DE/Wald-Fischerei/02_Internationale-Waldpolitik/_texte/HolzbeschaffungErlass.html.

GRUBER, E. (2004): Makromolekulare Chemie, Ökologie und Ökonomie der Nachwachsenden Rohstoffe: Nutzung von Lignin. (Memento vom 27. Juli 2004 im Internet Archive) Unterlagen zur Vorlesung Wintersemester 1999/2000.

GRUBLER, A., F. AGUAYO, K. GALLAGHER, M. HEKKERT, K. JIANG, L. MYTELKA et al. (2012): Chapter 24 – Policies for the Energy Technology Innovation System (ETIS). Global Energy Assessment – Toward a Sustainable Future. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria: 1665.

HAGEMANN, N., E. GAWEL, A. PURKUS, N. PANNICKE and J. HAUCK (in prep.): Possible futures towards a wood-based bioeconomy: A scenario analysis for Germany.

HÄNNINEN, R., L. HETEMÄKI, E. HURMEKOSKI, A. MUTANEN, A. NÄYHÄ, J. FORSSTRÖM, J. VIITANENE and T. KOLJONEN (2014): European Forest Industry and Forest Bioenergy Outlook up to 2050: A Synthesis. Cleen Oy, Helsinki.

HANSJÜRGENS, B. (2000): Symbolische Umweltpolitik – Eine Erklärung aus Sicht der Neuen Politischen Ökonomie. In: Hansjürgens, B. and G. Lübbe-Wolff (eds.): Symbolische Umweltpolitik. Suhrkamp, Frankfurt am Main.

HARVEY, M. and S. PILGRIM (2011): The new competition for land: Food, energy, and climate change. In: Food Policy 36 (Supplement 1): 40-51.

HERRMANN, F., J. SANDEN, T. SCHOMERUS and F. SCHULZE (2012): Ressourcenschutzrecht – Ziele, Herausforderungen, Regelungsvorschläge. In: Zeitschrift für Umweltrecht 23 (10): 523-526.

HOCKING, M.B. (1997): Vanillin: Synthetic Flavoring from Spent Sulfite Liquor. In: Journal of Chemical Education 74 (9): 1054-1059.

HOLZHANDELS-SICHERUNGS-GESETZ (HOLZSIG) (2011): Holzhandels-Sicherungs-Gesetz vom 11. Juli 2011 (BGBl. I S. 1345), das durch Artikel 415 der Verordnung vom 31. August 2015 (BGBl. I S. 1474) geändert worden ist.

HOMAMI, S.S., M.K. SEYDEI and S. MORADI (2013): Preparation of Wood Plastic Composite from Polyethylene and Bagasse. In: Middle-East Journal of Scientific Research 14 (4): 453-455.

ISERMEYER, F. and Y. ZIMMER (2006): Thesen zur Bioenergie-Politik in Deutschland. Arbeitsberichte des Bereichs Agrarökonomie 02/2006, Bundesforschungsanstalt für Landwirtschaft. URL: http://www.specialissue.iamo.de/fileadmin/veranstaltungen/isermeyer_praesentation.pdf, accessed 26 March 2015.

JAFFE, A.B., R.G. NEWELL and R.N. STAVINS (2005): A tale of two market failures: Technology and environmental policy. In: Ecological Economics 54 (2-3): 164-174.

JENKINS, J.D. (2014): Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design? In: Energy Policy 69: 467-477.

KAJASTE, R. (2014): Chemicals from biomass – managing greenhouse gas emissions in biorefinery production chains – a review. In: Journal of Cleaner Production 75: 1-10.

KALT, J. and M. ZUPAN (1984): Capture and Ideology in the Economic Theory of Politics. In: American Economic Review 74 (3): 279-300.

KAMM, B., M. KAMM, M. SCHMIDT, T. HIRTH and M. SCHULZE (2006): Lignocellulose-based Chemical Products and Product Family Trees. In: Kamm, B., P.R. Gruber and M. Kamm (eds.): Biorefineries – industrial processes and products. Status quo and future directions. Wiley-VCH, Weinheim: 97-149.

KANGAS, H.-L., J. LINTUNEN and J. UUSIVUORI (2009): The cofiring problem of a power plant under policy regulations. In: Energy Policy 37 (5): 1898-1904.

KARUS, M. and M. KAUB (2001): Naturfasern für die europäische Automobilindustrie. Nova-Institut, Hürth. URL: http://www.nova-institut.de/pdf/studie-naturf-auto.pdf.

KEMP, R., J. SCHOT and R. HOOGMA (1998): Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. In: Technology Analysis and Strategic Management 10 (2): 175-198.

KEOHANE, N., R. REVESZ and R. STAVINS (1998): The Choice of regulatory instruments in environmental policy. In: Harvard Environmental Law Review 22 (2): 313-367.

KLEMM, D., B. HEUBLEIN, H.-P. FINK and A. BOHN (2005): Cellulose: faszinierendes Biopolymer und nachhaltiger Rohstoff. In: Angewandte Chemie 117 (22): 3422–3458.

KÖCK, W. and K. KERN (2006): Öffentlich-rechtliche Kontrolle von Umweltrisiken, insbesondere Probleme und Perspektiven der europäischen Chemikalienkontrolle. In: Vieweg, K. (ed.): Risiko-Recht, Verantwortung. Heymanns Verlag, Köln: 279-320.

KRIPPNER, R. (2004): Untersuchungen zu Einsatzmöglichkeiten von Holzleichtbeton im Bereich von Gebäudefassaden. Dissertation. Technische Universität München.

LAHL, U. (2014): Bioökonomie für den Klima- und Ressourcenschutz – Regulative Handlungskorridore. Study on behalf of NABU (Nature And Biodiversity Conservation Union). BLZ Kommunikation und Projektsteuerung GmbH, Oyten.

LEHMANN, P. and E. GAWEL (2013): Why should support schemes for renewable electricity complement the EU emissions trading scheme? In: Energy Policy 52: 597-607.

LEHMANN, P., F. CREUTZIG, M.-H. EHLERS, N. FRIEDRICHSEN, C. HEUSON, L. HIRTH and R. PIETZCKER (2012): Carbon Lock-Out: Advancing Renewable Energy Policy in Europe. In: Energies 5 (2): 323-354.

LETTAU-TISCHEL, S. (2012): Dresden setzt Weltstandards – Leichtbau: Elektromobilität verbindet – Region im Schaufenster Elektromobilität Bayern-Sachsen. Präsentation, Amt für Wirtschaftsförderung. Dresden. URL: http://www. mfd-dresden.com/fileadmin/MFD-Dateien/Bilder/PDF/Dresden_Leichtbau_MFD_2012_deutsch.pdf, accessed 26 March 2015.

LEWANDOWSKI, I. and A.P.C. FAAIJ (2006): Steps towards the development of a certification system for sustainable bio-energy trade. In: Biomass and Bioenergy 30 (2): 83-104.

LIMAYEM, A. and S.C. RICKE (2012): Lignocellulosic biomass for bioethanol production: Current perspectives, potential issues and future prospects. In: Progress in Energy and Combustion Science 38 (4): 449-467.

LUDWIG, G., C. TRONICKE, W. KÖCK and E. GAWEL (2014): Rechtsrahmen der Bioökonomie in Mitteldeutschland – Bestandsaufnahme und Bewertung. UFZ Discussion Paper 22/2014. Leipzig. URL: http://www.ufz.de/export/data/global/63262_DP_22_2014_Bioeconomy1.pdf, accessed 18 March 2015.

LUDWIG, G., C. TRONICKE, W. KÖCK and E. GAWEL (2015a): Der Rechtsrahmen für die Bioökonomie in Deutschland. In: Die Öffentliche Verwaltung 68 (2): 41-53.

LUDWIG, G., E. GAWEL and N. PANNICKE (2015b): Schließung von Stoffkreisläufen am Beispiel von HTC-Brennstoffen. In: Wasser und Abfall 17 (10), in press.

MANTAU, U. (2012): Holzrohstoffbilanz Deutschland – Entwicklungen und Szenarien des Holzaufkommens und der Holzverwendung von 1987 bis 2015. Universität Hamburg.

MCCANN, L. (2013): Transaction costs and environmental policy design. In: Ecological Economics 88: 253-262.

MCCORMICK, K. (2011): The emerging bio-economy in Europe: Exploring the key governance challenges. In: World renewable Energy Congress 2011, Sweden. URL: http://lup.lub.lu.se/record/1774406, accessed 7 September 2015.

MCCORMICK, R.E. and R.D. TOLLISON (1981): Politicians, Legislation and the Economy: An Inquiry into the Interest-Group Theory of Government. Martinus-Nijhoff, Boston.

MCCORMICK, K. and N. KAUTTO (2013): The Bioeconomy in Europe: An Overview. In: Sustainability 5 (6): 2589-2608.

MICHALK, K. (2015): The legal framework for short rotation coppice in Germany in the context of the 'greening'of the EU's common agricultural policy. In. Manning, D.B., A. Bemmann, M. Bredemeier, N. Lamersdorf and C. Ammer (2015): Bioenergy from Dendromass for the Sustainable Development of Rural Areas. Wiley VCH, Weinheim.

MOISEYEV, A., B. SOLBERG and A.M.I. KALLIO (2014): The impact of subsidies and carbon pricing on the wood biomass use for energy in the EU. In: Energy 76: 161-167.

NAUMANN, K., K. OEHMICHEN, M. ZEYMER, F. MÜLLER-LANGER, M. SCHEFTELOWITZ, P. ADLER, K, MEISEL and M. SEIFFERT (2014): DBFZ Report Nr. 11: Monitoring Biokraftstoffsektor. DBFZ, Leipzig.

NORTH, D.C. (1990): Institutions, institutional change and economic performance. Cambridge University Press, Cambridge.

– (1995): Five propositions about institutional change. In: Knight, J. and I. Sened (eds.): Explaining social institutions. University of Michigan Press, Ann Arbor: 15-26.

OBER, S. (2015): Noch ganz am Anfang. Viele offene Fragen beim Ausbau der Bioökonomie. URL: https://www.nabu.de/umwelt-und-ressourcen/ressourcenschonung/biooekonomie/19308.html, accessed 7 September 2015.

ORCHARD, L. and H. STRETTON (1997): Critical survey: public choice. In: Cambridge Journal of Economics 21 (3): 409-430.

PACINI, H., L. ASSUNÇÃO, J. VAN DAM and R. TONETO JR (2013): The price for biofuels sustainability. In: Energy Policy 59: 898-903.

PANNICKE, N., N. HAGEMANN, A. PURKUS and E. GAWEL (2015): Gesellschaftliche Grundfragen der Bioökonomie: Volkswirtschaftliche Mehrwerte und Nachhaltigkeitsherausforderungen der biobasierten Wirtschaft. UFZ Discussion Paper 7/2015, Leipzig.

PELTZMAN, S. (1976): Toward a more general theory of regulation. In: Journal of Law and Economics 19 (2): 211-240.

PERRINGS, C. and D.I. STERN (2000): Modelling Loss of Resilience in Agroecosystems: Rangelands in Botswana. In: Environmental & Resource Economics 16 (2): 185-210.

PEUKER, U.A., A. KWADE, U. TEIPEL, H.-G. JÄCKEL and T. MÜTZE (2012): Aufbereitungstechnik: Aktuelle verfahrenstechnische Fragestellungen für die Aufbereitung von mineralischen, nachwachsenden und sekundären Rohstoffen. Position paper of the expert group ProcessNet, an initiative of Dechema and VDI-GVC. ProcessNet, Frankfurt (Main).

PFAU, S.F., J.E. HAGENS, B. DANKBAAR and A.J.M. SMITS (2014): Visions of Sustainability in Bioeconomy Research. In: Sustainability 6 (3): 1222-1249.

PURKUS A., M. RÖDER, E. GAWEL, D. THRÄN and P. THORNLEY (2015): Handling Uncertainty in Bioenergy Policy Design – A Case Study Analysis of UK and German Bioelectricity Policy Instruments. In: Biomass and Bioenergy, in press.

RICHARDSON, B. (2012): From a fossil-fuel to a bio-based economy: the politics of industrial biotechnology. In: Environment and Planning C: Government and Policy 30 (2): 282-296.

RING, I. (2007): Evolutionary strategies in environmental policy. In: Ecological Economics 23 (3): 237-249.

RL AUW/2007: Richtlinie des Sächsischen Staatsministeriums für Umwelt und Landwirtschaft zur Förderung von flächenbezogenen Agrarumweltmaßnahmen und der ökologischen Waldmehrung im Freistaat Sachsen (Förderrichtlinie Agrarumweltmaßnahmen und Waldmehrung – RL AuW/2007) vom 13. November 2007. Berichtigt 2. Januar 2008 (SächsABl. S. 228), zuletzt geändert durch RL vom 29. Juli 2014, (SächsABl. S. 974) mit Wirkung vom 1. Januar 2014. Teil A: flächenbezogene Agrarumweltmaßnahmen (UM).

RODI, M., S. SINA, B. GÖRLACH, C. GERSTETTER, C. BAUSCH and A. NEUBAUER (2011). Das Klimaschutzrecht des Bundes – Analyse und Vorschläge zu seiner Weiterentwicklung. Climate Change 17/2011. UBA, Dessau-Roßlau.

ROHLFS, J. (1974): A theory of interdependent demand for a communications service. In: Bell Journal of Economics 5 (1): 16-37.

SANDBERG, D., P. HALLER and P. NAVI (2013): Thermo-hydro and thermo-hydro-mechanical wood processing: An opportunity for future environmentally friendly wood products. In: Wood Material Science & Engineering 8 (1): 1, 64-88.

SCARLAT, N. and J.-F. DALLEMAND (2011): Recent developments of biofuels/bioenergy sustainability certification: A global overview. In: Energy Policy 39 (3): 1630-1646.

SCHELLING, T.C. (1978): Micromotives and macrobehavior. Norton & Company, New York and London.

SCHMIDT, R.C. and R. MARSCHINSKI (2009): A model of technological breakthrough in the renewable energy sector. In: Ecological Economics 69 (2): 435-444.

SCHNEIDER, F. and J. VOLKERT (1999): No chance for incentive-oriented environmental policies in representative democracies? A Public choice analysis. In: Ecological Economics 31 (1): 123-138.

SCHUBERT, R. and J. BLASCH (2010). Sustainability standards for bioenergy: A means to reduce climate change risks? In: Energy Policy 38 (6): 2797-2805.

SHEPPARD, A.W., S. RAGHU, C. BEGLEY, P. GENOVESI, P. DE BARRO, A. TASKER and B. ROBERTS (2011): Biosecurity as an integral part of the new bioeconomy: a path to a more sustainable future. In: Current Opinion in Environmental Sustainability 3 (1-2): 1-7.

SÖDERHOLM, P. and R. LUNDMARK (2009): The Development of forest-based Biorefineries: Implications for Market Behavior and Policy. In: Forest Products Journal 59 (1-2): 6-16.

SRU (The German Advisory Council on the Environment) (2007): Climate change mitigation by biomass. Special report. Berlin.

STAFFAS, L., M. GUSTAVSSON and R. MCCORMICK (2013): Strategies and Policies for the Bioeconomy and the Bio-Based Economy: An Analysis of Official National Approaches. In: Sustainability 5 (6): 2751-2769.

STIGLER, G. (1971): The theory of economic regulation. In: Bell Journal of Economics and Management Science 2 (1): 3-21.

STROHM, K., J. SCHWEINLE, M. LIESEBACH, B. OSTERBURG, A. RÖDL, S. BAUM, H. NIEBERG, A. BOLTE and K. WALTER (2012): Kurzumtriebsplantagen aus ökologischer und ökonomischer Sicht, Arbeitsberichte aus der vTI-Agrarökonomie, No. 06/2012.

STRUNZ, S. (2014): The German energy transition as regime shift. In: Ecological Economics 100: 150-158.

STUPAK, I., I. STUPAK, A. ASIKAINEN, M. JONSELL, E. KARLTUN, A. LUNNAN, D. MIZARAITE, K. PASANEN, H. PÄRN, K. RAULUND-RASMUSSEN, B. RÖSER, M. SCHROEDER, I. VARNAGIRYTE, L. VILKRISTE, I. CALLESEN, N. CLARKE, T. GAITNIEKS, M. INGERSLEV, M. MANDRE, R. OZOLINCIUS, A. SAARSALMI, K. ARMOLAITIS, H-S. HELMISAARI, A. INDRIKSONS, L. KAIRIUKSTIS, K. KATZENSTEINER, M. KUKKOLA, K. OTS, H.P. RAVN and P. TAMMINEN (2007): Sustainable utilisation of forest biomass for energy-possibilities and problems: policy, legislation, certification, and recommendations and guidelines in the Nordic, Baltic, and other European countries. In: Biomass and Bioenergy 31.10 (2007): 666-684.

THRÄN, D., M. EDEL, J. PFEIFER, J. PONITKA, M. RODE and S. KNISPEL (2011): DBFZ Report Nr. 4: Identifizierung strategischer Hemmnisse und Entwicklung von Lösungsansätzen zur Reduzierung der Nutzungskonkurrenzen beim weiteren Ausbau der Biomassenutzung. DBFZ, Leipzig.

TUERK, A., A. COWIE and A. LEOPOLD (2011): The influence of Emissions Trading Schemes on bioenergy use. IEA Bioenergy Task 38 – Greenhouse Gas Balances of Biomass and Bioenergy Systems. URL: http://task38.org/T38_ETS_Bioenergy_2011.pdf, accessed 2 November 2015.

UNRUH, G.C. (2000): Understanding carbon lock-in. In: Energy Policy 28 (12): 817-830.

UNRUH, G.C. (2002): Escaping carbon lock-in. In: Energy Policy 30 (4): 317-325.

UPHAM, P., RIESCH, H., TOMEI, J. and THORNLEY, P. (2011): The sustainability of forestry biomass supply for EU bioenergy: A post-normal approach to environmental risk and uncertainty. In: Environmental Science & Policy 14(5): 510-518.

VAN DEN BERGH, J.C. and G. KALLIS (2013): A survey of evolutionary policy: normative and positive dimensions. In: Journal of Bioeconomics 15 (3): 281-303.

VANDERMEULEN, V., M. VAN DER STEEN, C.V. STEVENS and G. VAN HUYLENBROECK (2012): Industry expectations regarding the transition towards a biobased economy. In: Biofuels, Bioproducts and Biorefining 6 (4): 453-464.

VCI (Verband der Chemischen Industrie e.V.) (2012): Chancen und Grenzen des Einsatzes nachwachsender Rohstoffe in der chemischen Industrie. Frankfurt (Main).

WBA (Wissenschaftlicher Beirat Agrarpolitik beim Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) (2007): Nutzung von Biomasse zur Energiegewinnung – Empfehlungen an die Politik. Berlin.

WBGU (German Advisory Council on Global Change) (2008): Future Bioenergy and Sustainable Land Use. Berlin.

WEHSENER, J., T.-E. WERNER, J. HARTIG and P. HALLER (2014): Advancements for the Structural Application of Fiber-Reinforced Moulded Wooden Tubes. In: Aicher, S., H.-W. Reinhardt and H. Garrecht (eds.): Materials and Joints in Timber Structures – Recent Developments of Technology. Springer, Netherlands.

WEI, S.-J. (1997): Gradualism versus Big Bang: speed and sustainability of reforms. In: The Canadian Journal of Economics 30 (4b): 1234-1247.

WEISS, M., J. HAUFE, M. CARUS, M. BRANDÃO, S. BRINGEZU, B. HERMANN and M.K. PATEL (2012): A Review of the Environmental Impacts of Biobased Materials. In: Journal of Industrial Ecology 16 (S1): 169-181.

WWF GERMANY (2008): Illegaler Holzeinschlag und Deutschland. Eine Analyse der Außenhandelsdaten. Frankfurt (Main).

WYDRA, S., B. HÜSING and P. KUKK (2010): Analyse des Handlungsbedarfs für das Bundesministerium für Wirtschaft und Technologie (BMWi) aus der Leitmarktinitiative (LMI) der EU-Kommission für biobasierte Produkte außerhalb des Energiesektors. Fraunhofer Institut für System- und Innovationsforschung (ISI), Karlsruhe.

WYMAN, C. and B. GOODMAN (1993): Biotechnology for production of fuels, chemicals, and materials from biomass. In: Applied Biochemistry and Biotechnology. 39-40 (1): 41-59.

2009/28/EC: Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable resources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

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