Drivers of the European Bioeconomy in Transition (BioEconomy2030)

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Abstract

The bioeconomy is at the centre of many EU challenges such as growth and jobs creation, climate change, food security and resource depletion. This paper analyses the resilience of the EU bioeconomy towards contrasting, medium-term visions characterised by diversified policy instruments. To this purpose, a state-of-the-art modelling framework, supported with a database specifically extended for the need of the analysis of a future EU bioeconomy, are employed. Possible evolutions of the traditional and newer bio-based sectors in the EU are studied under two futures characterized by polar choice in terms of agricultural, trade, biofuel and climatic EU policies. Both exploratory scenarios are compared with a baseline built as a most plausible future in 2030. In analysing the challenges of the bioeconomy, the paper focuses on the issue of policy coherence, using a decomposition methodology to evaluate the isolated impact of each policy within the formulated scenarios. The underlying message of the analysis is that the bioeconomy in the EU is set to face considerable challenges in the future.

Key words

bioeconomy, modelling, agriculture, CGE, CAP, biofuel, trade, GHG

1. Introduction

A key component of the European Union (EU) Bioeconomy Strategy (EC, 2012) is to stimulate research and development activities which can identify and enhance knowledge of best practise in biomass usage across different end uses and concomitantly, generate policy recommendations to reconcile the broad goals of (*inter alia*) wealth generation and employment, food security, responsible resource usage and environmental preservation.

Casual observation reveals that biomass policies in the EU are fragmented (i.e., the Common Agricultural Policy (CAP); biofuels mandates; 2020 climate and energy package), which potentially leads to policy inconsistency. For example, encouraging biomass usage for energy may adversely affect carbon sequestration and therefore GHG emissions limits. Similarly, implementing a strategy for responsible sustainable growth (i.e., maintaining biodiversity, cultural landscapes and renewable energy) may induce limits on employment generation. Thus, the key challenge is one of 'policy coherence', which, it is recognised, must allow for, "*...fair competition between the various uses of biomass resources* (across competing sectors)", although even the interpretation of 'fair' remains open to debate (Hamje et al., 2014, p.7).

In recognition of the immediate need to take action, a wide range of qualitative and quantitative EU funded foresight studies have emerged with a medium term (2030+) horizon. Although overlapping, a number of studies focus of specific aspects of the aforementioned (interconnected) challenges, ranging from issues of land use (VOLANTE, 2010), food security (FoodSecure, 2012, Maggio et al., 2015) agri-food market trends (von Lampe et al., 2014b), or 'positioning' reports on the current and possible future state of the bioeconomy (EC, 2015). A common theme in all of these studies is the design of alternate futures, each of which acknowledges that decisions taken today have repercussions for future generations. These 'pathways' therefore characterise diverse socio-political and -economic visions which govern the cognitive processes behind policy making. From a methodological standpoint, quantitative foresight assessments (VOLANTE, 2010, FoodSecure, 2012, von Lampe et al., 2014b), resort to a neoclassical multi-region computable general equilibrium (CGE) representation. This class of mathematical simulation model has become a *de facto* toolbox of choice, since it encapsulates all sectors and economic actors (national and global) within a fully comprehensive, consistent and closed economic system of equations.

In the current EU focused study, a quantitative foresight exercise is carried out to examine the future prospects for bio-based sectors. A key aim is to understand the resilience of the EU bioeconomy in the face of contrasting medium-term (i.e., 2030) visions characterised by a portfolio of diversified bio-based policy instruments. This implies state-of-the-art modelling of said policies and a careful design to implement precise policy shocks. Given the globally interconnected nature of biomass markets, a credible foresight study must explicitly capture world market developments. For this reason, the current study also employs a multi-region CGE approach, calibrated to the well-known Global Trade Analysis Project (GTAP) database (Narayanan et al., 2015). An important scientific development is that significant data enhancements are made to include additional sources of biomass supply and demand which go far beyond the standard definitions within the national accounts used in GTAP. As a direct response to the key question of policy coherence, the research seeks to understand the relative strength of the policy drivers in shaping bio-based market trends in each of the different narratives and to flag up, where present, policy conflicts.

The rest of this paper is structured as follows: Section two describes the methodology and scenario design. Sections three and four discuss the results of the baseline and scnearios, respectively. Section five concludes.

2. Methodology and Scenario Design

2.1 Model and Data

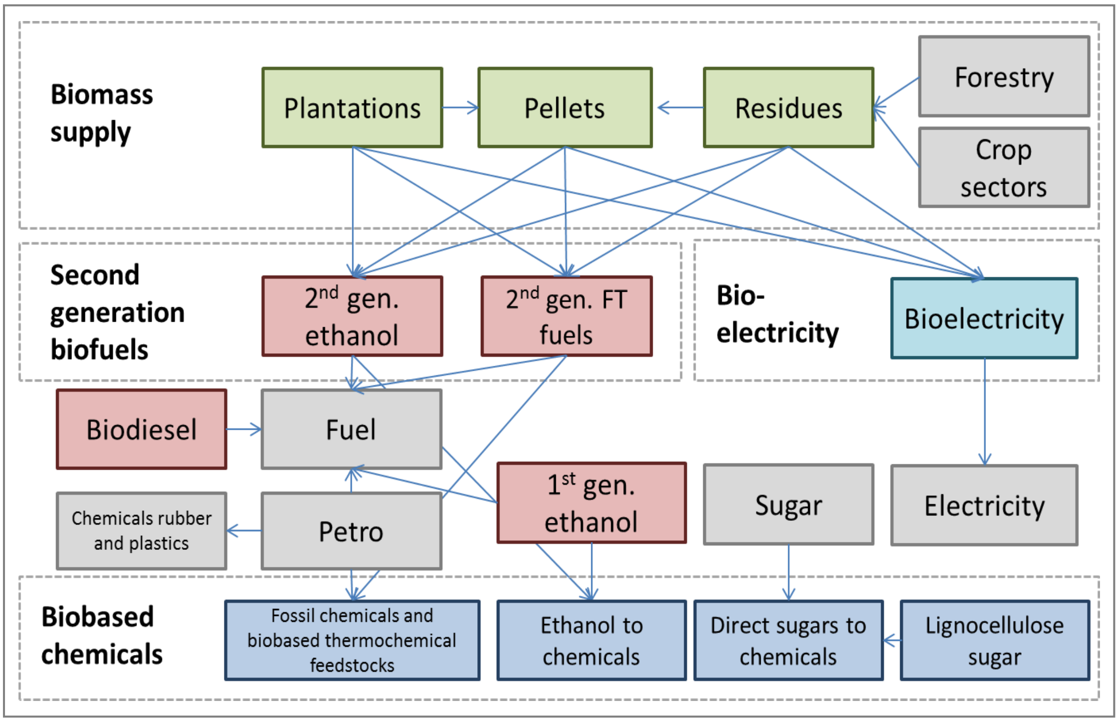
The well documented GTAP model (Hertel, 1997) and associated database (Narayanan et al., 2015) form the basis of the current research. In essence, the model relies on a mathematical representation of neoclassical microeconomic optimisation to enumerate demand and supply behaviour. Subject to a series of exogenous variable shocks (i.e. tax, productivity or factor endowments), prices and outputs endogenously adjust subject to the underlying market clearing and Keynesian macroeconomic accounting equations to ensure an 'equilibrium' (i.e., supply equals demand, zero profits, macro aggregates balance).

For the purposes of the current study, a series of data and modelling innovations are included to depict in detail, different sources of biomass supply (i.e., residues, plantations and pellets), first generation biofuels (from sugar, starch and oil crops), second generation biofuels produced from lignocellulosic biomass (residues, plantations, pellets), bio-electricity and biochemical activities using conventional agricultural crops and lignocellulose biomass. In short, as well as extending current bio-based activities beyond the traditional national accounts classification, the research also includes 'new' technologies (i.e. second generation biofuels) which, hitherto, are still in their infancy but may be expected to play a key role in shaping the bioeconomy in the medium term.

To undertake the required sector splits and rebalancing required in the GTAP database, data on production volumes, conversion efficiencies, cost structures, and trade and transport costs were collected for the benchmark year of 2007. Most of the data on the new bio-based sectors come from relevant studies and models. In particular data on production, conversion efficiencies, costs of capital, operation & maintenance and other production costs come from the IMAGE model from the Netherlands Environmental Assessment Agency (Daioglou et al., 2015). The sustainable potential of (lignocellulose) residues in the EU is based on results from the Biomass Policies project (Elbersen, 2015). On the other hand, data for the rest of the world are taken from Daioglou et al., (2015). A full list of these sources is extensively described in van Meijl et al., (2016).

The result is a new subset of data linkages both between the new bio-based sectors and with the rest of the economy. Figure 1 provides a schematic illustration of these linkages, where the coloured boxes represent 'new' bio-based sectors and the grey boxes are usual GTAP sectors. The arrows indicate the direction of the biomass and bio-based energy and chemicals flows. For example, the fuel sector mixes petroleum with first generation and second generation biofuels.

Figure 1 Overview of bio-based sectors and linkages in the model database.



Source: Van Meijl, 2016, p. 63.

To this database, an advanced recursive dynamic variant of the GTAP model, known as the Modular Applied GeNeral Equilibrium Tool (MAGNET) (Woltjer and Kuiper, 2014), is calibrated. The MAGNET model provides flexibility to choose from a list of non-standard modules to address the most pertinent aspects of the study at hand. The version of the

MAGNET model employed here explicitly treats the specificities of agricultural factors (the main source of biomass generation) and input markets to cater for input substitution possibilities, heterogeneous land transfer and relative wage differentials between agricultural and non-agricultural labour and capital. In addition, given the time dimension of the study, the model captures changes in the pattern of (agri-food) demand elasticities resulting from structural economic change (Woltjer and Kuiper, 2014). A Leontief joint production technology is assumed in forestry and agricultural sectors to model residue by-products, whilst the same modelling technique is used to treat oilcake and distiller's dried grains and soluble (*DDGS*) feeds by-products from first generation bio-diesel and bio-ethanol sectors. Explicit modelling of biomass policies borrows from the latest developments in the literature. More specifically, additional modules capture the latest reforms of the Common Agricultural Policy (CAP) (Boulanger and Philippidis, 2015), first generation fiscally neutral biofuel blending mandates (Banse et al., 2008) and greenhouse gas (GHG) emissions reductions and carbon taxes (Burniaux and Truong, 2002).

To aid the exposition, the paper draws on the results decomposition method of ‘subtotals’ (Harrison *et al.*, 2000). More specifically, on running a complex scenario with an array of shocks (i.e., endowments, tariffs, technology change etc.), this methods allow calculating the part-worth of the resulting endogenous variable change that corresponds to a specific exogenous shock, or pre-specified group of exogenous shocks. Thus, when comparing each of the scenarios with the baseline, the comparative ‘part-worth’ importance of the four main policy indicators plus the macroeconomic projections and the changes in world energy prices are evaluated to better understand the role that policies and exogenous assumptions have to play (if any) in shaping bio-based market trends.

2.2 Aggregation and Closure

The database is disaggregated into 49 tradable goods, of which 39 are bio-based sectors (Table 1). To more adequately characterise production decisions within bio-based activities, non-bio-based inputs are also included (i.e., feeds, fertilisers, fossil fuels). With an EU focus, the largest EU member states players are included, as well as EU regions where bioeconomic activity (primarily, agriculture) is relatively important (i.e., Ireland and Poland). Further EU member state disaggregation reflects pragmatic modelling considerations to incorporate the rebate mechanism of the CAP budget (Boulanger and Philippidis, 2015), whilst Croatia is separated to model its entry to the EU and associated CAP budget. For the non-EU regions, 'large players' (both net exporters and importers) and impoverished partners on world bio-based markets are identified. All residual trade and output flows are captured within a Rest of the Word (ROW) region.

A standard neoclassical closure rule is employed where the balance on the trade account and the capital account net to zero. In EU regions with additional intra-community CAP payments flows, adjustments are made to regional savings to ensure that the general equilibrium circular flow condition of the data remains intact.

Table 1: GTAP data aggregation

2.3. Baseline and Scenario Design

The baseline (BL) design is spread over three time intervals (2007-2013; 2013-2020; 2020-2030) which are chosen to coincide with the EU's multiannual financial framework, Croatia's EU accession and the EU's climate and energy package 2020. The BL encompasses past and 'foreseeable' future market developments focusing on the EU's main bio-based activity policy drivers (i.e., CAP, trade policy; biofuel mandates and GHG reductions). The first period (2007-2013) captures the main historical market trends, whilst the 2013-2030 timeframe is described in Table 2.

In addition to policy shocks, projections of population and real GDP growth taken from von Lampe et al. (2014b) are assumed to follow a *status quo* baseline trend. In MAGNET, labour endowments mimic population changes (fixed employment rates), capital shadows real GDP trends (fixed medium to long-run capital-output ratio), whilst natural resources are assumed to grow at one-quarter the rate of the capital stock. Given the importance of bioenergy markets in the EU, World Bank (2015) medium term world price shocks to fossil fuels are also implemented.

Table 2: Assumptions shaping the 'status quo' baseline scenario (2013-2020-2030)

As a departure from the BL, two paradigms are identified for the decade 2020-2030 which take polar paths to epitomise changes in the EU's stature within a hypothetical world order (Table 3). These alternate futures are characterised by the degree of priority placed on each of the four policy pillars: CAP, trade, biofuels and GHGs. Classified as *inward*- and *outward-looking* policy worlds (henceforth known as 'IL' and 'OL'), the underlying ethos is the degree to which the EU attempts to marry tangible goals (e.g., economic growth and employment generation), with philanthropic concepts of poverty reduction (e.g., improve the incomes of poorer countries through 'fairer' trade), environmental protection, biodiversity and green growth (i.e., GHG emissions limits, CAP Policy), as well as reduced fossil fuel dependence (e.g., biofuel policy) (Table 3).

Thus, in the OL scenario the EU behaves as an altruistic leader on the world stage. More specifically, the EU is leading the fight on reducing GHG emissions (in the absence of any binding commitments at the United Nations Climate Change Conference in Paris in December 2015, only proposed EU reductions in GHGs are implemented), whilst championing a 'greener' vision for the CAP. Energy policy is more orientated toward modern bio-based solutions, whilst the EU also has an instrumental role in forging a multilateral trade deal to help alleviating poverty.

The IL scenario takes an introspective approach to EU policy making. The EU moves toward existing fossil fuel technologies and promotes only neighbourhood and regional trade alliances. Finally, agricultural markets follow a more market oriented policy approach.

Table 3: Assumptions shaping alternative policy paths (2020-2030)

3 Baseline Results (2013-2030)

3.1 EU Bioeconomy Output

The general trend (Table 4) is that bio-based EU activities grow at a relatively slower rate than the economy-wide average, such that resources are gradually diverted away from the bioeconomy. Furthermore, as EU real GDP is assumed to rise at a slower pace than almost all non-EU countries, EU trade competitiveness is eroded resulting in output falls. This is of particular relevance to 'open' bio-based (i.e., textiles, wearing apparel, leather and wood products), and fertiliser activities, which exhibit lower EU self-sufficiency ratios.

Compared with the 31.7 index point rise in real GDP growth, primary agriculture remains static (increase of 1.9 index points), whilst higher value-added food production volume rises 12.3 index points. In part, this is due to low income elasticities on final demands for agricultural and food products. In addition, under the assumption of higher land productivities increases in non EU regions, there is greater import competition in EU agriculture.

Table 4: EU bio-based output volume changes

Biomass supply (includes plantations, residues and pellets), bioenergy (1st and 2nd generation biofuels and bio-electricity) and bio-chemical sectors all record impressive output growth, albeit from small production bases. Compared with 2013, by 2030 bio-chemical, biomass and bioenergy activities increase by a factor of 1.36, 2.16 and 3.12, respectively. The effect of the mandate is especially clear in bioenergy, and by extension, biomass providing sectors (which in turn supply less to bio-chemicals activities). With falling biofuel prices accompanied by strong projected price rises in crude oil over the decade 2020-2030, a strong substitution effect in favour of biofuels is observed.

The downward trend observed in EU market prices partly reflects economy wide (Hicks neutral) productivity growth to meet targeted real GDP growth rates.

3.2 EU Bioeconomy Employment

The employment trends measured in thousands of head for the EU bio-based sectors are presented in Table 5. Following the output trends EU bioeconomy employment falls from an estimated 17.8 million persons in 2013 to 13.6 million by 2030. The results show increasing employment opportunities in the bioenergy sector (from 19,000 to 79,000), although this cannot mitigate the general trend that by 2030, bio-based employment share will fall from 8.1% in 2013 to 5.7% in 2030.

Table 5: EU bio-based employment (1000's head)

3.3 Land Markets

In MAGNET, parameterised estimates of land response by each of the GTAP regions are taken from a physical land use model known as IMAGE (Eickhout et al., 2009). The results show that by 2030 for most regions land usage remains reasonably close to 2013 levels (Table 6). In the majority of cases, the increased need for land resulting from real growth, endowment and population projections is outweighed by land productivity improvements (projections). In the EU, land usage falls by 2.2 index points. As EU CAP payments contract, marginal land leaves agricultural production (-0.7 index points). Perhaps surprisingly, the biofuel mandate only generates slight increases in EU land use (0.1 index points), accompanied by increases in North America, and Mercosur from increases in EU bioenergy imports. On the other hand, the fall in Japanese land usage by 10 index points reflects the assumptions of relatively weak real GDP growth, population decline and larger GHG reductions.

Table 6: Region land use

4. Scenario Results (2020-2030)

4.1 EU Bioeconomy Output

Comparing the IL with the BL, the EU real growth (0.2%) and the EU per capita utility or real income (0.4%) show a slight improvement (Table 7). Examining the shocks decomposition, the only policy contributor to this result is the elimination of the biofuel mandate. The EU's decision to strengthen its neighbourhood policy and promote TTIP yields limited gains (0.01% GDP growth). This result reflects the eliminations in relatively low average applied tariff rates while no reductions in 'behind the border' non-tariff measures (NTMs) are modelled. Similarly, the elimination of all non-green Pillar 1 payments in a relatively 'small' sector such as agriculture in the EU, unsurprisingly, has very little macroeconomic impact.

Table 7: Macro indicators (%) from the IL and OL scenarios compared with the BL (2020-2030)

A different story emerges comparing the OL and BL scenarios. Real GDP in the EU falls 1.2% over the 2020-2030 decade, accompanied by a corresponding fall of 1.6% in real per capita incomes compared to the baseline. Over the 2020-2030 decade, multilateral trade reform is expected to generate moderate trade led GDP gains (0.1%). With more ambitious unilateral GHG reductions in the EU, the resulting rise in carbon taxes acts as a further constraint on EU growth (relative GDP fall of 1%).[1] Similarly, higher biofuel mandate also leads to a relative GDP fall of 0.6%. This fall is mainly due to the biomass supply bottlenecks. The mandate significantly increases biofuel prices, forces reductions in fossil fuel usage, depresses petroleum output, and therefore stifles economic growth. As the EU's bio-based and non-bio-

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[1] By 2030, the 'average' EU28 carbon tax per tonne of CO2 equivalent (CO2e) of GHG emissions is €15/tonne CO2e in the baseline, €27/tonne CO2e in the IL scenarios and €95/tonne CO2e in the OL scenario (not shown).

based activities contract, non-EU regions witness small real growth gains (not shown).[2] The GHG reductions generate smaller welfare losses than the biofuel mandate (despite generating larger relative real output falls), since GHG reductions are accompanied by tax revenue increases.

The impact of the policy narratives on the EU bioeconomy output volumes is presented in Tables 8 and 9. Comparing the IL scenario with the BL (Table 8), the main message is that the isolated impact from the elimination of the biofuel mandate and associated fiscal support is clearly detrimental to the survival of the bioenergy sector (-91.4%), as well as the bio-based supply sector (-49.6%). Furthermore, this shock also generates further negative ripple effects for adjacent bioenergy feedstock and residue supply sectors (i.e., agriculture, forestry). The biochemical sector benefits (19%) as a (now) more attractive alternative source of biomass usage, whilst the large aggregate sectors of fossil fuels and energy and the rest of the economy ('rest') also expand as primary resources are reallocated to non bioeconomy sectors.

Table 8: Output volume changes (%) between the IL and BL scenarios (2020-2030)

Comparing output change in the OL and BL scenarios (Table 9), the implication of increasing the biofuel mandate is to increase output in biomass supply (68%) and bioenergy (45%) activities, as well as in residue and feedstock supplies from agriculture and forestry. In addition, there is a multiplier effect in those downstream sectors that employ agriculture (food) and forestry (wood) products. On the other hand, in the large aggregate sectors (fossil fuel energy and ‘rest’), this policy generates output falls of -2.2% and -0.6%, respectively, leading to lower macro growth (as discussed above). The CAP has a similar output effect as in the IL scenario, although less pronounced given the re-distribution of Pillar 1 market support payments to Pillar 2 (rural development) objectives.

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[2] Over the 2020-2030 period, as a percentage of GDP, the largest relative gains are estimated for India (0.9%), China (0.3%), Mercosur (0.2%) and the USA (0.2%) (not shown)

Table 9: Output changes (%) between the OL and BL scenarios (2020-2030)

The isolated impacts of the projections and world fossil fuel price shocks (unchanged from the BL), have significant incremental impacts for bioenergy activity when comparing with the BL, although starting from a small base. In the IL scenario (Table 8), as the mandate is eliminated, non-EU countries are also dumping cheaper biofuel exports (to the detriment of EU domestic production), whilst general rises in factor prices and the increased cost of (now non-subsidised) biofuel inputs within the blending sector makes fossil fuel alternatives appear to be more attractive. In the OL scenario (Table 9) the increasing mandate pushes up the price of bioeconomy supply and second generation biofuels, which makes crude oil a more attractive prospect for petroleum refining. Similarly, with lesser (land) supply constraints in other countries (i.e., Mercosur and North America) and better growth prospects, there is more spare capacity for biofuels production.

4.2 Bioeconomy Employment

Exploiting employment data from 2013 (Ronzon et al., 2015), the employment trends measured in thousands of head for the EU28 bio-based sectors are presented in Table 10. As expected, the trends are driven by the output changes reported in section 3.2. A large proportion of bio-based employment is centred in the agricultural sector, which in the IL scenario contracts by 251,000 workers. This resulting loss of employment from EU agrifood production explains much of the fall in EU bio-based sector employment under this scenario. In addition, IL employment prospects in the bioenergy sector are reduced significantly (-69,000 workers) and are not compensated by the small increase in traditional sectors as textile and wearing apparel (+1000 each) and the biochemical one (+5000).

Table 10: EU28 bio-based employment (1000's head) and share (%)

Comparing the OL with the BL, the primary agricultural sector sheds even more workers (approximately 360,000). Based on the output drivers, this results is a combination of (in order of magnitude) unilateral EU GHG emissions reductions, multilateral trade deal and CAP policy. Some job growth is recorded in the forestry and wood products sectors, whilst the bioenergy sector, despite the higher mandate, sheds 29,000 workers owing to the drop in derived demand from the downstream petroleum (blending) sector arising from the higher EU GHG reductions. Despite a very different combination of policy shocks in the IL and OL scenarios, the share of employment in bio-based activities falls to 5.6% (compared with 5.7% in the BL).

4.3 Bioenergy Markets

Table 11 illustrates the evolution of bioenergy production as a value share of total energy supply by country/region. With the EU's steady promotion of biofuels in the BL, increases in non-EU bioenergy output (particularly Mercosur) are required to compensate the shortfall in internal EU production. By 2030, the EU bio-based energy falls from 5.3% of the total in the BL to 0.6% in the IL scenario. As the EU reduces its import dependence on biofuels, bioenergy production shares in non-EU regions fall, where the most marked effect is in Mercosur. In the OL scenario, the EU's bioenergy output share rises to 9.1% in 2030. Noteworthy rises in EU import demand for bioenergy benefit non-EU producers, with the largest percentage point rises occurring in North America and Mercosur.

Table 11: Output value share of bioenergy (%) in total energy production

With removal of the biofuel mandate in the IL scenario, the isolated impact of the loss of the blending subsidy increases the relative market price of petroleum by 1.5% (Table 12). On the other hand, with reduced demand for biofuel inputs, there are relative market price falls in first generation biodiesel and biogasoline, whilst the cost of second generation inputs also falls (approximately 26 to 27%).

Comparing the OL and BL scenarios, the decomposition of the policy drivers shows that the bioenergy blending mandate plays an important role. This role is played in combination with greater EU GHG emissions reductions. Focusing on the impact of the former, the price of second generation (thermal and biochemical) biofuels and bio-electricity sectors soars compared with the BL (approximately 800%). This is the result of a highly ambitious second-generation mandate (raised from 1.5% to 5%) which generates bottlenecks in the supply of feedstock from the infant industry activities of plantations, pellets and residues. As the necessary biofuel input subsidy rises to target this mandate, the (blended) petroleum price falls (-1.5%). Moreover, a substitution away from fossil fuels combined and an economic slowdown (negative real income) effect from the biofuel policy, reduces prices in other energy commodities.

Table 12: Changes in energy prices compared with the BL (2020-2030)

The other driving policy in the OL scenario is the additional unilateral reduction in EU GHG emissions. Through the imposition of further carbon taxes, there is an increase in the EU's energy bill for final consumers of electricity (7.8%), gas (7.0%) and petroleum (3.1%), compared with the BL. The resulting output contraction in these refining and processing energy industries from higher EU GHG emissions reductions reduces derived demand for crude oil, gas, and bio-based energy inputs, thereby depressing market prices. Coal is used intensively in electricity generation and it is assumed to be relatively less substitutable, thus electricity demand for coal falls by less.

4.4 Land Usage

In Table 13 are presented the proportion of land devoted to first generation biofuels production in each of the regions by 2030. In the IL scenario, the elimination of the EU biofuel regime results in an almost total removal of biofuel land usage when compared with the BL. By 2030, compared with a 3.3% share of EU land in the BL, the EU biofuel land share drops to approximately 0.3%. As discussed above, in the non-EU regions, the cessation of EU biofuel mandates also reduces biofuel land usage in Mercosur (from 2.7% to 1.1%) and North America (from 6.3% to 1.5%), compared to the baseline.

Table 13: Evolution of land share (%) devoted to 1st generation biofuels by narratives

In the OL scenario, *a priori* it can be expected to find increased land shares devoted to biofuel production with policy induced increases in the blending mandates. The simulation, however, shows that the impact of the EU's additional GHG emissions reduces derived demand for bio-based (and fossil based) fuels through the blending (petroleum) sector, leading to lower land usage compared with the baseline. Once again, the percentage point drop in biodiesel land usage is greater due to its greater input intensity in the EU blending industry. As the EU blending sector contracts, EU import demands for biofuels also fall, although Mercosur biodiesel land shares remain at a buoyant level, due to the greater opening of global markets under the multilateral trade negotiations.

5. Conclusions

Employing a state-of-the-art CGE modelling framework supported with a database specifically extended for the need of this research and a decomposition technique to individuate part-worth impact of multiple shocks, this paper shed some light on possible evolution of the bioeconomy sectors in the EU. A baseline scenario depicting a plausible future in 2030 is compared with two alternative worlds characterized by polar choice in terms of agricultural, trade, biofuel and climatic EU policies. If in one scenario the EU behaves as an altruistic leader on the world stage leading the fight on reducing GHG emissions, another scenario depicts the EU taking an introspective approach to policy making moving toward existing fossil fuel technologies and promoting neighbourhood and regional trade alliances.

Macroeconomic projections are the exogenous factor affecting most the macro and sectorial results presented; nevertheless the analysis shows the importance of the four policy pillars analysed (CAP, biofuel, trade and GHG) in shaping the future of the EU bioeconomy.

The underlying message of the analysis is that the bioeconomy in the EU is set to face considerable challenges in the future. The importance of the bio-based sectors is expected to dwindle somewhat, both as a motor of jobs and growth. Macroeconomic results show that the IL scenario brings a negligible GDP and real income increase while these variables face a more significant reduction under the OL scenario mainly driven by the cost associated to more ambitious biofuel and GHG emission policies.

A part from the CAP, whose impacts are limited on both scenarios, the three remaining policies have significant impacts on growth of EU bio-based sectors. An abolition of the biofuel mandate depresses biomass supply and bioenergy while the doubling of the mandate boost those sector while crowding-out the biochemical one.

Regional trade as adopted in the IL has negligible effects on the economy while a multilateral agreement impacts negatively on the sectors currently more protected and more exposed to international competition such as agriculture, food industry and textile or clothing.

Finally, more ambitious GHG reduction affects adversely the agriculture but also, through backward effects due to the fall of fossil fuel, on the bioenergy and biomass.

Despite these sectorial changes, employment reductions in bio-based sectors in the two scenarios are comparable to the BL one.

Looking with more details into the bioenergy sector, policy shows a great impact in shaping both the share of bioenergy over total produced energy and in prices. In the OL scenario, if as expected share of bioenergy raises significantly, the bottlenecks in supply of feedstock to the second generation biofuel industry causes dramatic increase in the prices of bioelectricity and second generation biofuels.

Despite the noticeable advancements in the analysis if the future EU bioeconomy sector, there are still areas which could benefit from further research. The biggest improve cold come from an additional effort in terms of data which could be further enhanced to include a better treatment of forestry (currently at an aggregate level) as well as account for the complex and promising "marine bioeconomy".

A further point for future research is represented by the climate policies modelling. Whilst the model is currently fully equipped with behavioural equations to characterise different permit trading schemes and/or carbon tax policies, there remain areas for improvement. On the one hand, linking to the point above, a more recent version of the GTAP data will require a complete data set of GHG (CO2 and non CO2) emissions data. Perhaps even more importantly, land based sequestration of emissions are also not included in the current study. As a result, in its current form, the study does not account for the important role that alternative land uses (i.e., forestry and agriculture) could play in meeting GHG emissions targets and the far reaching implications this has for land using bio-based sectors.

An additional aspect to keep in mind is the treatment of technological adaptation across different economic activities. Under the current assumption regarding the evolution of global GHG emissions, the incorporation of endogenous technological change mechanisms would undoubtedly generate a more optimistic picture of the evolution of (bio-based) economic activity in the EU.

To conclude, this paper represents an innovative contribution in providing a viable methodological framework for enumerating the opportunities and threats facing the collective of bio-based activities and in addressing the issue of policy coherence.

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Tables

Table 1: GTAP data aggregation

Sectoral disaggregation (49 commodities):

Primary agriculture (10 commodities): wheat; other grains; oilseeds; raw sugar; vegetables, fruits and nuts; other crops; cattle and sheep; pigs and poultry; raw milk; crude vegetable oil.

Food and beverages (5 commodities): meat; dairy; sugar processing; vegetable oils and fats; other food and beverages.;

Other 'traditional' bio-based activities (7 Commodities): fishing; forestry; textiles; wearing apparel; leather products; wood products; paper products and publishing.

Biomass supply (5 commodities): plantations; residue processing; pellets; by-product residues from agriculture; by-product residues from forestry.

Bio-based energy (5 commodities): 1st generation biodiesel; 1st generation bioethanol; bioelectricity; 2nd generation thermal technology biofuel; 2nd generation biochemical technology biofuel.

Bio-based chemicals (4 commodities): lignocelluose sugar; polylactic acid; polyethylene mixed bio/fossil chemicals.

Bio-based and non bio-based animal feeds (3 commodities): bioethanol by-product distillers dried grains and solubles; biodiesel by-product oilcake; animal feed.

Fertiliser (1 commodity): fertiliser.

Fossil fuels and energy (6 commodities): crude oil; petroleum; gas; gas distribution; coal; electricity.

Other sectors (3 commodities): chemicals, rubber and plastics; transport; other sectors.

Regional disaggregation (23 regions):

EU members (12 regions): United Kingdom (UK); Netherlands and Sweden (NLSWE); Denmark (DK); Germany (GER); Austria (AUT); France (FRA); Ireland (IRE); Italy (ITA); Poland (POL); Spain (SPA); Rest of the EU27 (RoEU27); Croatia (CRO)

Non EU regions (11 regions): United States of America (USA); Canada (CAN); Mercosur (MERC); Russian Federation (RUS); China (CHN); India (IND); Japan (JAP); Australia & New Zealand (AUSNZ); Middle East & North Africa (MENA); Sub-Saharan Africa (SSA); Rest of the World (ROW).

Table 2: Assumptions shaping the 'status quo' baseline scenario (2013-2020-2030)

2013-2020 period

Projections

- Skilled and unskilled labour, capital, natural resources, population, and real GDP (von Lampe et al, 2014b).

Trade Policy

- EU28 Enlargement elimination of border protection between incumbent EU27 members and Croatia.
- Extension to Croatia of an EU common external tariff (CET) on third country trade and reciprocal third country CETs extended to Croatia as an EU28 member.
- Elimination of remaining EU28 tariffs with Peru, Columbia and South Korea.
- 40% (time linear) applied tariff reductions between Canada and the EU28 (agreement assumed enacted in 2016).

- Non reciprocal EBA EU tariff eliminations extended to Croatia.

Agricultural Policy

- Pillar 1 and Pillar 2 nominal expenditures are cut 13% and 18%, respectively (European Council, 2013). This corresponds to a 15.2% cut in nominal CAP budgetary funding.
- Phasing in of decoupled payments for 2007 accession members and Croatia.
- Greening of 30% of Pillar 1 payments, represented as Pillar 2 agro-environmental payments.
- Pillar 2 payments extended to Croatia.
- Abolition of raw milk (2015) and raw sugar (2017) quotas.
- Croatia incorporated within the CAP budget and UK rebate mechanism.
- Projected reduction in CAP expenditure share of the EU budget consistent with 15.2% cut in nominal CAP budget reduction.
- Change in Swedish, Dutch and Danish lump sum rebates corresponding to CAP expenditure share in EU budget. UK rebate is maintained (European Council, 2013).

Bioenergy Policy

- EU28-wide 1st generation biofuel mandate of 7%; EU28-wide 2nd generation biofuel mandate of 1.5%.

Environmental Policy

- Global greenhouse gas emissions reductions consistent with business as usual projections (Labat et al., 2015).

Fossil Fuel Prices

- Impose projections of expected changes in world prices for coal, gas and crude oil (World Bank, 2015).

2020-2030 period

Projections

- Skilled and unskilled labour, capital, natural resources, population, and real GDP (von Lampe et al, 2014b).

Trade Policy

- Elimination of remaining EU28 tariffs with Canada.

Agricultural Policy

- Projected reduction in CAP expenditure share of the EU budget.
- Change in Swedish, Dutch and Danish lump sum rebates corresponding to CAP expenditure share in EU budget.
- UK rebate is maintained

Bioenergy Policy

- Blending targets are relaxed, although the real value of (fiscally neutral) subsidy support is held fixed.

Environmental Policy

- GHG emissions reductions consistent with business as usual projections (Labat et al., 2015).

Fossil Fuel Prices

- Impose expected changes in world prices for coal, gas and crude oil (World Bank, 2015).

Table 3: Assumptions shaping alternative policy paths (2020-2030)

Inward looking (2020-2030 period) – baseline projections and world fossil fuel price shocks plus:

Trade Policy

- Elimination of remaining EU28 tariffs with Canada.
- Elimination of all EU-USA tariffs under a TTIP agreement.
- EU FTAs under the Eastern Partnership (Armenia, Azerbaijan, Belarus, Georgia, Moldova), the Balkans (Bosnia and Herzegovina, Macedonia, Montenegro, Serbia), North Africa (Algeria, Egypt, Morocco, Tunisia, Western Sahara) and Turkey.

Agricultural Policy

- Removal of all remaining Pillar 1 expenditures.
- Projected reduction in CAP expenditure share of the EU budget consistent with elimination of Pillar 1.
- Change in Swedish, Dutch and Danish lump sum rebates corresponding to CAP expenditure share in EU budget. Consistent with elimination of Pillar 1.
- UK rebate is maintained.

Bioenergy Policy

- All blending mandates and existing subsidy support to the blending industry are removed.

Environmental Policy

- GHG emissions reductions are unchanged from the baseline.

Outward looking (2020-2030 period) – baseline projections and world fossil fuel price shocks plus:

Trade Policy

- Elimination of remaining EU28 tariffs with Canada.
- Multilateral 50% reduction in all applied tariffs in all partner countries.

Agricultural Policy

- All remaining Pillar 1 expenditures are uniformly distributed into Pillar 2 (CAP budget neutral compared with the baseline).
- Projected reduction in CAP expenditure shares and lump sum rebates are the same as the baseline.
- UK rebate is maintained.

Bioenergy Policy

- Increase mandate targets for 1st (10%) and 2nd (5%) generation biofuels. Policy remains fiscally neutral.

Environmental Policy

- EU GHG emissions reductions consistent with existing EU proposals to further reduce GHG emissions by 43% compared with 1990 levels. In remaining regions, GHG emissions reductions are unchanged from the baseline (Labat et al., 2015).

Table 4: EU bio-based output volume changes[3]

	Index 2013=100		Decomposition of index by shocks (2013-2030)					
	2020	2030	Proj	WP	CAP	Trade	Biofuel	GHG
agriculture	100.1	101.9	5.0	0.2	-0.1	0.0	0.3	-3.6
food processing	104.0	112.3	13.8	0.1	0.0	0.2	0.2	-2.0
forestry	103.2	108.8	4.9	0.1	0.0	0.0	1.9	1.9
textiles	88.7	80.7	-18.1	-0.3	0.0	0.0	0.0	-0.9
wearing apparel	86.0	76.7	-24.5	0.0	0.0	0.1	0.0	1.1
leather products	74.8	59.5	-39.5	0.0	0.0	0.1	0.0	-1.0
wood products	96.6	95.3	-7.5	-0.2	0.0	0.0	0.5	2.5
paper products	107.6	118.8	19.4	0.0	0.0	0.0	0.0	-0.6
biomass supply	194.0	216.3	13.9	1.2	0.0	0.0	104.1	-3.1
bioenergy	157.5	311.9	150.9	20.3	0.1	0.0	47.4	-6.7
biochemicals	111.3	136.1	61.0	-1.6	1.9	-0.4	-20.4	-4.4
fossil fuel & energy	109.1	112.4	14.4	3.3	0.0	0.0	-0.1	-5.3
rest	113.1	132.0	32.5	0.1	0.0	0.0	-0.1	-0.6
real GDP	113.3	131.7	31.8	0.2	0.0	0.0	-0.1	-0.2
per capita utility	113.1	128.9	28.5	0.6	0.0	0.0	-0.1	-0.2

Proj=all region's projections shocks; WP=fossil fuel world prices; CAP=CAP policy; trade=Trade policy; Biofuel=Biofuel policy; GHG=Greenhouse gas policy

Table 5: EU bio-based employment (1000's head)

	2013	2020	2030
Bio-based employment	17,774	16,207	13,550
Agriculture	9,980	9,189	7,822
Food processing	4,676	4,307	3,632
Forestry	505	449	345
Fishing	173	170	157
Textiles	226	180	112
Wearing apparel	375	289	169
Leather products	158	107	50
Wood products	1,043	893	640
Paper products	593	569	518
Bioenergy	19	27	79
Bio-chemicals	26	26	27
Share of total (%)	8.08	7.20	5.73

Source: Eurostat (2015) and own calculations

Note: In all but two sectors, employment data for 2013 was taken from Eurostat (2015). In the biofuels sector, a 2011 EU estimate of 19,000 workers is employed (Piotrowski and Carus, 2015), whilst employing the same reference, it is assumed that five percent of the chemical sector workforce is dedicated to bio-chemical production. The employment data (thousands of head) are generated from a side calculation using the percentage change in labour units demanded calculated within the main model.

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[3] Proj=all region's projections shocks; WP=fossil fuel world prices; CAP=CAP policy; Trade=Trade policy; Biofuel=Biofuel policy; GHG=Greenhouse gas policy

Table 6: Region land use

	2013=100		Decomposition of index (2013-2030)					
Land use	2020	2030	Proj	WP	CAP	Trade	BF	GHG
EU28	98.3	97.8	-1.5	0.1	-0.7	0.0	0.1	-0.2
North America	97.9	96.0	-1.3	0.7	0.0	-0.5	0.4	-3.3
Mercosur	100.3	105.3	-15.4	1.0	0.0	0.1	0.4	19.2
Russia	99.8	96.0	-2.7	0.4	0.0	0.1	0.3	-2.1
China	103.2	104.3	4.1	0.0	0.0	0.0	0.0	0.2
India	100.1	100.2	0.1	0.0	0.0	0.0	0.0	0.0
Japan	97.2	90.3	-9.4	-0.2	0.0	0.0	0.1	-0.1
Rest	97.2	99.5	-15.1	-1.7	0.0	0.1	0.1	16.2

Table 7: Macro indicators (%) from the IL and OL scenarios compared with the BL (2020-2030)

			Decomposition by shocks vs. BL (2020-2030)						
IL vs BL	BL	IL	Proj	WP	CAP	Trade	Biofuel	GHG	IL vs BL
Real GDP	16.3	16.5	0.0	0.1	0.0	0.0	0.1	0.0	0.2
Per capita utility	14.0	14.4	0.1	0.0	0.0	0.0	0.2	0.0	0.4
OL vs BL	BL	OL	Proj	WP	CAP	Trade	Biofuel	GHG	OL vs BL
Real GDP	16.3	15.1	0.1	0.1	0.0	0.1	-0.6	-1.0	-1.2
Per capita utility	14.0	12.4	0.2	0.3	0.0	0.0	-1.3	-0.8	-1.6

Table 8: Output volume changes (%) between the IL and BL scenarios (2020-2030)

			Decomposition by shocks vs. BL (2020-2030)						Tot.diff
IL vs BL	BL	IL	Proj	WP	CAP	Trade	Biofuel	GHG	IL vs BL
Agriculture	1.7	-2.3	-0.8	-0.9	-1.0	-0.1	-1.2	0.0	-4.0
food processing	7.9	5.6	-0.7	-0.4	-0.2	-0.2	-0.7	0.0	-2.2
Forestry	5.6	3.5	-0.6	0.0	0.0	-0.1	-1.2	-0.1	-2.1
Textiles	-8.9	-8.3	0.2	-0.1	0.0	0.4	0.0	0.0	0.6
Wearing apparel	-11.0	-10.3	0.3	0.0	0.0	0.3	0.1	0.0	0.7
Leather products	-20.1	-19.6	0.4	-0.2	0.1	0.2	-0.1	0.1	0.5
Wood products	-1.4	-2.0	-0.3	0.1	0.1	0.0	-0.4	-0.1	-0.6
Paper products	10.3	10.2	-0.1	0.1	0.0	0.0	0.0	0.0	-0.1
Biomass supply	23.3	-33.1	-5.6	-0.7	0.2	-0.4	-49.6	-0.2	-56.4
Bioenergy	133.4	-66.2	-76.5	-33.8	-0.2	0.0	-91.4	2.2	-199.6
Biochemical	17.8	42.9	3.9	2.3	-0.1	-0.1	19.3	-0.1	25.2
Fos fuel & energy	2.9	1.1	-2.2	0.3	0.0	0.0	0.1	-0.2	-1.8
Rest	16.6	16.8	0.0	-0.1	0.0	0.0	0.1	0.1	0.1

Table 9: Output changes (%) between the OL and BL scenarios (2020-2030)

	Decomposition by shocks vs. BL (2020-2030)	Tot.diff

OL vs BL	BL	OL	Proj	WP	CAP	Trade	Biofuel	GHG	OL vs BL
Agriculture	1.7	-4.4	-0.7	0.1	-0.6	-1.6	1.2	-4.5	-6.1
food processing	7.9	4.3	-0.8	-0.4	-0.2	-1.8	1.2	-1.6	-3.6
Forestry	5.6	27.2	-12.2	-1.0	0.0	0.3	41.0	-6.6	21.5
Textiles	-8.9	-13.1	-0.1	0.0	0.0	-6.6	0.4	2.0	-4.3
Wearing apparel	-11.0	-14.1	0.2	0.0	0.0	-6.2	0.2	2.8	-3.1
Leather products	-20.1	-22.3	0.1	0.3	0.0	-6.1	0.5	3.0	-2.2
Wood products	-1.4	5.3	-2.2	-0.7	0.0	0.3	8.9	0.5	6.7
Paper products	10.3	10.3	-0.1	-0.2	0.0	0.2	0.6	-0.5	0.0
Biomass supply	23.3	58.0	-20.4	-3.5	0.1	0.2	68.0	-9.8	34.7
Bioenergy	133.4	57.7	-74.2	-39.0	0.0	0.1	44.9	-7.5	-75.7
Biochemical	17.8	-1.0	9.7	2.6	0.0	-0.9	-35.6	5.6	-18.8
Fos fuel & energy	2.9	-8.6	-0.1	0.1	0.0	0.2	-2.2	-9.6	-11.6
Rest	16.6	14.9	-0.3	0.5	0.0	0.1	-0.6	-1.4	-1.7

Table 10: EU28 bio-based employment (1000's head) and share (%)

	2030 BL	2030 IL vs. BL	2030 OL vs. BL
Bio-based employment	13,550	-384	-306
Agriculture	7,822	-251	-360
Food industry	3,632	-54	-67
Forestry	345	-8	90
Textiles	112	1	-5
Wearing apparel	169	1	-6
Leather	50	0	-1
Wood	640	-3	42
Paper	518	0	2
Bioenergy	79	-69	-29
Biochemicals	27	5	-3
Share of total (%)	5.73	5.57	5.60

Table 11: Output value share of bioenergy (%) in total energy production

	2013	2020	2030 BL	2030 IL	2030 OL
EU28	1.8	2.9	5.3	0.6	9.1
N. America	1.8	1.7	2.9	0.7	3.3
Mercosur	2.4	2.5	5.3	2.0	5.9
Russia	0.0	0.0	0.0	0.0	0.1
China	0.5	0.6	1.5	0.3	1.8
India	0.2	0.2	0.6	0.3	1.0
Japan	0.3	0.4	0.3	0.3	1.1
RoW	0.1	0.1	0.2	0.1	0.4

Table 12: Changes in energy prices compared with the BL (2020-2030)

			Decomposition by shocks vs. BL (2020-2030)						Tot.diff
IL vs BL	BL	IL	Proj	WP	CAP	Trade	Biofuel	GHG	IL vs BL
crude oil	30.0	30.0	0.3	-0.5	0.0	0.1	-0.1	0.3	0.1
petroleum	9.7	13.2	1.5	0.4	0.0	0.0	1.5	0.1	3.5
biodiesel	-18.4	-27.0	-0.5	-2.5	0.2	0.0	-6.1	0.3	-8.6
biogasoline	-15.2	-29.5	0.1	-1.9	0.4	-0.1	-13.5	0.7	-14.3
gas	10.5	10.2	-0.2	-0.2	0.0	0.0	0.0	0.1	-0.3
coal	29.7	32.2	1.9	0.0	-0.1	0.3	0.1	0.3	2.5
electricity	-10.5	-7.9	2.6	-0.7	0.0	0.1	0.1	0.5	2.6
gas distribution	-9.3	-7.1	2.1	-0.7	0.0	0.1	0.2	0.5	2.2
bio-electricity	-15.1	-48.1	-2.4	-4.9	0.1	-0.2	-25.8	0.3	-33.0
thermal 2^{nd}-gen	-15.2	-48.4	-2.7	-4.8	0.1	-0.3	-25.8	0.3	-33.2
bio-chem 2^{nd}-gen	-15.3	-49.6	-2.8	-5.0	0.1	-0.3	-26.7	0.3	-34.3
			Decomposition by shocks vs. BL (2020-2030)						Tot.diff
OL vs BL	BL	OL	Proj	WP	CAP	Trade	Biofuel	GHG	OL vs BL
crude oil	30.0	29.4	0.2	1.4	0.0	-0.1	-1.1	-1.1	-0.6
petroleum	9.7	13.6	1.3	1.2	0.0	-0.1	-1.5	3.1	3.9
biodiesel	-18.4	-23.1	-3.1	-0.8	0.1	-0.3	-0.5	-0.2	-4.8
biogasoline	-15.2	-19.9	-3.6	-0.4	0.4	-0.5	0.0	-0.6	-4.7
gas	10.5	7.8	-0.4	0.2	0.0	0.0	-0.3	-2.1	-2.6
coal	29.7	44.5	4.1	0.3	-0.1	-0.6	-4.6	15.7	14.8
electricity	-10.5	-3.5	-0.4	1.9	0.0	-0.4	-1.9	7.8	7.0
gas distribution	-9.3	-3.2	0.6	1.9	0.0	-0.4	-2.9	7.0	6.1
bio-electricity	-15.1	306.4	-332.3	-2.8	-0.7	2.9	803.5	-149.2	321.5
thermal 2^{nd}-gen	-15.2	301.2	-324.5	-2.8	-0.7	2.8	787.4	-145.9	316.3
bio-chem 2^{nd}-gen	-15.3	312.8	-336.8	-2.9	-0.7	2.9	817.0	-151.4	328.1

Table 13: Evolution of land share (%) devoted to 1st generation biofuels

2030 BL	EU	North America	Mercosur
biogasoline (1^{st}-generation)	1,25	3,47	1,01
biodiesel (1^{st}-generation)	2,04	2,85	1,69
1st generation biofuels	3,29	6,32	2,71
2030 IL vs. BL	EU	North America	Merc
biogasoline (1^{st}-generation)	-1,17	-2,33	-0,66
biodiesel (1^{st}-generation)	-1,86	-2,49	-0,90
1st generation biofuels	-3,03	-4,82	-1,57
2030 OL vs. BL	EU	North America	Merc
biogasoline (1^{st}-generation)	-0,72	-0,25	-0,11
biodiesel (1^{st}-generation)	-0,99	-0,77	0,12
1st generation biofuels	-1,70	-1,02	0,01

Figures

Figure 1 Overview of bio-based sectors and linkages in the model database.