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Drivers of the European Bioeconomy in Transition

(BioEconomy2030)

an exploratory, model-based assessment

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FOREWORD

The United Nations 2030 Agenda for Sustainable Development, adopted in September 2015, provides a roadmap to set the world on a path of responsible resource usage and poverty eradication which, it is hoped, will lead to the even broader global goals of greater solidarity between nations, peace and prosperity. The three dimensions of sustainable development, namely the economic, social and environmental, are the triad shaping any future evolution, from global to local level.

For its part, the European Union is actively and ambitiously contributing to shape these multiple challenges. Several policy and action plans have been endorsed, among which the Bioeconomy Action Plan (2012) takes a particular integrative approach, comprising all those sectors of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy.

Although desirable, a fully integrated systems analysis to capture the interlinkages of all different bio-based sectors and actors is not yet available. Notwithstanding, the JRC-IPTS agro-economic modelling team, in collaboration with the LEI at The Hague, is conducting ongoing work to develop a promising approach capable of combining existing knowledge on economic, societal and political trends related to the bioeconomy sectors in a systematic and interconnected way.

More specifically, with a view to supporting the analysis of the European bioeconomy, whilst also providing a point of reference for subsequent work in this area, this report employs an advanced neoclassical computable general equilibrium (CGE) model, known as the Modular Applied GeNeral Equilibrium Tool (MAGNET). In the context of this research project, the MAGNET model has been further extended to incorporate cutting-edge modelling and data developments in order to capture a high degree of bio-based sectoral and policy detail.

The report includes a detailed contemporary 'business as usual' projection to 2030 with accompanying alternate narratives representing two hypothetical policy pathways. Employing a useful decomposition technique, the reader is given insightful access to the relative role of economic and policy drivers in shaping market trends. Furthermore, by comparing policy narratives with the reference scenario, the report assesses both the resilience of EU's bioeconomy in fulfilling a diverse portfolio of policy goals and identifies potential policy conflicts and trade-offs.

With this exploratory research, as well as other flagship studies employing tools from the JRC-IPTS iMAP modelling platform, the key aim is to enhance the EU's knowledge base, both in terms of high quality research and effective results dissemination. We are confident that future endeavours of this type will build on the methodological advances made in the current study, whilst continued feedback from varied stakeholders and improved data access will further enhance the analysis.

Giampiero Genovese, Head of JRC-IPTS AGRILIFE unit, March 2016

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EXECUTIVE SUMMARY

The bioeconomy comprises sectors that use renewable biological resources to produce food, materials and energy. It is at the centre of several global and EU challenges in the near future such as the creation of growth and jobs, climate change, food security and resource depletion.

"Bioeconomy 2030" projects a reference scenario ('business as usual') and compares it with two distinct policy narratives ('Outward-looking' and 'Inward-looking') to understand the drivers of EU's bioeconomy up to 2030, assess its resilience to fulfil such diverse policy goals and identify potential trade-offs.

As a motor of jobs and growth, the results indicate that the importance of the bio-based sectors is expected to dwindle somewhat. The factors underlying this result are mainly structural and related to comparably lower macroeconomic growth rates in the EU.

It is, however, conceivable that improved economic development or productivity improvements linked to EU investments in, for instance bio-based innovation, would produce a recognisably more optimistic outlook for the EU bioeconomy.

The global and European bioeconomy, which comprises those sectors of the economy that use renewable biological resources from land and sea to produce food, materials and energy, face multiple challenges.
This report employs a state of the art variant of a recognised multi-region, multi-sector computable general equilibrium (CGE) simulation model combined with cutting edge developments in databases, to examine the potential role of the bio-based industries, with a particular focus on the EU.

A key area of scientific novelty of this research is that the definition of the bio-based sector not only includes the more traditional activities (e.g., agriculture, food, forestry, fishing etc.), but is further extended to encapsulate new areas of bio-based sector growth such as biomass supply, biochemicals and bioenergy activities. To this end, the Global Trade Analysis Project (GTAP) database, which is typically employed as a basis for conducting multi-regional CGE simulations, has been greatly modified to incorporate a series of sector splits. These sector splits explicitly disaggregate a number of key bio-based activities from their parent industries. This enables the modeller to examine with much greater precision, the expected trends in these sectors under different scenario designs and assess the extent to which the bioeconomy is able to meet the numerous policy challenges it faces in the medium term. A further improvement to the GTAP database is that input decisions in the primary agricultural sector are considerably more transparent given the explicit representation of fertiliser and feed activities. On the modelling side, the Modular Applied GeNeral Equilibrium Tool (MAGNET) is enhanced with improved modelling of the Common Agricultural Policy (CAP) budget and the representation of greenhouse gases (GHGs) complete with different emissions reduction policy schemes.

A first aim of this research is to perform a prospective study that tries to encapsulate as much economic, biophysical and policy detail as possible, in order to design a reasonable 'business as usual' or status quo scenario. Employing a decomposition analysis of the main drivers, this reference scenario serves as a vehicle for understanding the key drivers of the EU bioeconomy. To add further scientific value to the study, additional data developments are incorporated to explicitly represent and analyse the development of new bio-based activities such as bioeconomy supply (i.e., plantations, residues, pellets), 1st and 2nd generation bio-energies, bioelectricity and biochemical sectors.
In a second step, a departure from the reference scenario consists of two further narratives which represent different 'policy visions' of the EU's self-perception within a hypothetical world order. The first is an 'outward-

looking' policy narrative which treats the EU as a more altruistic leader on the world stage. More specifically, the EU is willing to embrace the challenge of climate change by leading the fight on reducing GHG emissions, whilst championing a 'greener' vision for the Common Agricultural Policy. Energy policy is more orientated toward a bio-based solution, whilst the EU also has an instrumental role in forging a multilateral trade deal in helping to alleviate poverty. The second policy narrative, known as 'inward-looking', takes an introspective approach to policy making. The EU moves toward existing fossil fuel technologies and promotes neighbourhood and regional trade alliances of a more strategic nature. Finally, agricultural markets are subject to a more market orientated policy approach.

By comparing both policy narratives with the reference scenario, the objective is to assess the resilience of the EU's bioeconomy in fulfilling a diverse portfolio of policy goals and identify, where relevant, potential policy conflicts and trade-offs.

MODEL DESIGN

- Modular Applied GeNeral Equilibrium Tool (MAGNET)
- Global Trade Analysis Project (GTAP) database modified to incorporate traditional sectors (e.g., agriculture, food, forestry, fishing etc.), and new bio-based activities such as biomass supply (i.e., plantations, residues, pellets), 1st and 2nd generation bio-energies, bioelectricity and biochemical sectors
- Improved modelling of the Common Agricultural Policy (CAP) budget.
- Greenhouse gases (GHGs) complete with different emissions reduction policy schemes.

'OUTWARD-LOOKING'

- EU leads reduction of GHG emissions
- Energy policy orientated toward bio-based solutions
- Global trade deal to help alleviate poverty
- 'Greener' vision for the Common Agricultural Policy

'INWARD-LOOKING'

- EU focusses on existing fossil fuel technologies
- Neighbourhood and regional trade alliances
- Mainly market orientated policy approach to agriculture

REFERENCE SCENARIO (2013-2030): KEY RESULTS

The changes in real GDP growth and per capita income are dominated by macroeconomic projections shocks. Policy shocks have limited ‘economy-wide’ impacts.

The loss of relative competitiveness in the EU due to assumed slower rates of economic growth and land productivity, acts as a brake on larger bio-based activities such as primary agriculture, whilst reducing production in textiles, wearing apparel, leather and wood products activities.

For specific bio-based sectors, EU policy matters much more. Biofuel mandates generate growth in the infant bio-based industries of bioeconomy supply and bioenergy, whilst within agriculture biofuel feedstock activities (i.e., oilseeds, crude vegetable oil and oilcake) also grow.

Output growth is faster in the EU’s non bio-based sectors; the bioeconomy’s capacity to generate growth and employment is diminished.

Under the current features of the model and experiment assumptions, **greenhouse gas (GHG) emissions reductions, with their undisputed non market benefits for the planet, have adverse repercussions for EU agricultural output,** as well as indirect negative impacts on EU bioenergy and bioeconomy supply sectors due to the contraction in the blending (petroleum) sector.

Malthusian **fears of population growth and resulting food shortages are not substantiated in the current study.**

Owing to supply bottlenecks in small scale infant industries, the EU biofuel mandate increases prices of bio-based energy sources and world prices of bio-based supply and second generation energy commodities rise notably compared with other commodities due to rising EU import demands to meet internally mandated blending targets.

In 1st generation biofuels, such price rises do not occur since supply bottlenecks are not apparent (partly due to global land productivities and the higher scale of production in feedstock supply).

In EU primary agriculture, land usage falls slightly, accompanied by falling land rents and agricultural wages. Falling CAP payments contribute to the reduction in the capitalised value of EU land.

The biofuel mandate continues to shift EU land use toward biofuel usage. To meet EU blending requirements, this policy **also encourages regions like North America and Mercosur to dedicate more land to biofuel production.**

Under conditions of slower EU economic growth, the EU’s trade competitiveness in the bio-based sectors, in particular, textiles, wearing apparel, leather and wood products, declines. Changes in the EU trade deficit are mainly motivated by deteriorating bio-based trade balances. Moreover, increases in the EU biofuel mandate generate significant net imports of biofuels.

With the exception of biofuels, the EU’s trade pattern continues to move more toward extra-EU trade sources.

THE RESILIENCE OF EU'S BIOECONOMY UNDER DIFFERENT POLICY NARRATIVES

The following sections summarise the key results comparing the reference scenario (RS) with the 'inward-looking' (IL) and 'outward-looking' (OL) scenario under different perspectives: EU growth, jobs and competitiveness; sustainable resource usage; and food security. The percentage changes depict the accumulated changes over the period 2020 to 2030.

EU GROWTH, JOBS AND COMPETITIVENESS (2020-2030): KEY RESULTS

Compared with the reference scenario (RS), **the 'inward-looking' (IL) scenario generates a real income (0.4%) and real macro growth (0.2%) gain for the EU. Comparing the 'outward-looking' (OL) and RS, real incomes and growth contract by -1.6% and -1.2%, respectively.**

The EU's regional trade policy in the IL scenario slightly benefits textiles, clothing and leather industries, but continues to negatively impact on agriculture, food, forestry and fishing.

Under the OL scenario further ambitious EU GHG emissions reductions and increased biofuel mandates generate an additional cost to the EU GDP. This does not account for the non-market environmental benefits of the EU's GHG policy.

In the OL scenario, increasing the biofuel mandate (especially 2nd generation limits) increases growth in bioenergy and bioeconomy supply activities, whilst diverting resources away from biochemicals. The share of the bioeconomy increases compared with the RS (although, EU macroeconomic activity shrinks).

In the IL scenario, the main cause of incremental EU macro growth is the abolition of the biofuel mandate (0.13%).

In the IL scenario, the EU's bioenergy sectors are heavily exposed without the mandate in place. As a result, bioenergy output falls, although there is evidence of alternative uses of biomaterials in biochemicals production.

In the IL scenario, the loss of bioenergy as a viable motor of growth also has negative implications for bioeconomy supply, such that the relative bioeconomy share of EU total activity shrinks even further compared with the RS.

Compared with the RS, bio-based employment generation falls in both the IL (-384,000 workers) and OL (-306,000 workers) scenarios.

In the OL scenario, the modelled CAP change of Pillar 1, the multilateral trade deal and further GHG reductions negatively affect bio-based employment prospects, particularly the largest employer, primary agriculture. A combination of these shocks, as well as the general economic slowdown in the EU, depresses wages.

In the IL, the modelled CAP change and the elimination of biofuel policies has an unfavourable impact on bio-based employment. Although wages rise, due to economic growth, sectorally trapped agricultural labour witnesses a small wage fall.

Trade competitiveness is not significantly affected in either scenario. The removal of the mandate in the IL leads to a significant improvement of EU trade competitiveness in bioeconomy supply and biofuels as cheap surpluses are dumped on world markets. In contrast, the rise in the mandate in the OL scenario and the EU's resulting import requirements marks deterioration in trade competitiveness in both sectors.

SUSTAINABLE RESOURCE USAGE (2020-2030): KEY RESULTS

In the IL scenario, as the mandate is removed and subsidy support is taken away from the blending sectors, the reduction in demand depresses biofuel prices. Similarly, petroleum (blended) prices rise slightly due to the loss of the blending subsidy.

In the OL scenario, the more ambitious rise in blending mix for 2nd generation biofuels, coupled with supply bottlenecks in feedstock to these sectors, pushes up considerably the cost of second generation biofuels as well as bioelectricity. Additional GHG emissions reductions in the OL scenario increase the final prices of energy (carbon taxes) in petroleum, electricity and gas distribution, whilst depressing (falling input demands) crude oil, gas and bio-based input prices, especially those used in second generation bioenergy.

The survival of the biofuel industry is heavily linked to EU policy making. In the 2030 RS, the biofuel share of energy production is 5.3%. In the OL scenario, by 2030 this share increases to 9%, whilst in the IL scenario the corresponding statistic is 0.6%.

In the IL, the rapidly receding importance of bioenergy sectors is also reflected in the share of land committed to biofuel usage, which falls from 3.3% in the 2030 RS, to 0.3% in the 2030 IL scenario. In the OL scenario, reduced derived demands from EU blending sectors affected by more ambitious GHG reductions, outweigh the mandated rise in the blending commitments, such that the share of land committed to biofuel usage falls to 1.6%.

The impact of the modelled CAP change on land usage, land yields and stocking densities in both IL and OL scenarios is well defined. There is a clear relationship between Pillar 1 changes in both IL and OL scenarios (marginal land abandonment and rising yields and stocking densities) and Pillar 2 changes in the OL scenario (marginal land uptake and falling yields and stocking densities).

The GHG and multilateral trade policies in the OL scenario have significant negative impacts on the competitiveness and higher concentration of emissions in the livestock industries, resulting in falling stocking densities.

In the OL scenario, the strengthening of the biofuel mandate clearly promotes additional (marginal) land use in the EU and, through increases in imports of biofuels, land use in non-EU regions.

Similarly, land rents in the EU are also greatly affected by the lost capitalisation of removing decoupled Pillar 1 payments, as well as the mitigating rent gains (OL scenario only) arising from increases in Pillar 2 rural development agri-environmental and least favoured area programmes.

Changes in biofuel policy have an impact on land rents. The raising of the blending mandate in the OL scenario increases real land rents by 12.5%.

Compared with 187 tonnes of CO2e/km2 of land by 2030 recorded in the 2030 RS, the intensity of land emissions rises to 192 tCO2e/km2 in the IL scenario, and falls to 164 tCO2e/km2 in the OL scenario. In both IL and OL (to a lesser extent) scenarios, the modelled CAP change is found to drive up emissions intensity on land due to the removal of marginal land from production. Despite increasing biofuel mandates inherent within the OL scenario, additional GHG reductions are largely accountable for the net fall in the intensity of land emissions.

FOOD SECURITY (2020-2030): KEY RESULTS

In both IL and OL scenarios, EU agriculture production (-4.0% and -6.1%, respectively) and food production (-2.2% and -3.6%, respectively) falls compared with the RS.

The modelled CAP changes have a minimal impact given the decoupled nature of support, whilst even the multilateral trade reform of the OL scenario is not detrimental, reflecting the generally low level of applied tariffs on trade.

GHG reductions in the OL scenario put additional pressure to the EU food security (-4.5% and -1.5% in EU agriculture and food, respectively).

Agricultural and food consumer price effects are small in both scenarios. The modelled CAP change has a minor inflationary impact on consumer prices for agricultural and food produce, whilst the multilateral trade reforms in the OL scenario have a moderate agrifood price depressing effect.

As a measure of increasing EU wealth and prosperity, consumption patterns for food in the EU follow Engel's Law. With rising (falling) per capita incomes in the IL (OL) scenario compared with the reference scenario, the household food expenditure share falls (rises), although the differences are negligible.

Calorie intake in the EU has reached a plateau. In the lower per capita income countries, it continues to rise, especially in India and Sub-Saharan Africa. The scenarios have no discernible threat/benefit on calorie intake.

In agriculture and food sectors, self-sufficiency deteriorates one percentage point for processed food in the OL. This is driven by the multilateral trade deal. Whilst EU agricultural production is characterised as more extensive (modelled CAP change) and environmentally clean (lower GHG emissions), these policy initiatives generate a cost in terms of lost food production.

1 THE GLOBAL CONTEXT OF THE EUROPEAN BIOECONOMY TOWARDS 2030

This chapter introduces the multiple challenges of the global and European bioeconomy, which comprises those sectors of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy.

The main European policy initiatives are presented, shaping the past and future development of the sector. Most of them have the common objectives of reducing the environmental impacts while fostering economic growth.

A literature review of relevant foresight and scenario analyses completes the rationale of the present study and outlines the structure of the report.

1.1 Between a perfect storm and optimistic visions

In the 21st century, the issues of climate change, natural resource depletion, population growth and food security, to name but a few, are posing challenging questions for researchers and policy makers.

On global political level, targets such as the Sustainable Development Goals (SDGs, United Nations, 2015b) or the United Nations Framework Convention on Climate Change (COP21, United Nations, 2015c) , agreed under the auspices of the United Nations in the second half of 2015, are responses to the main challenges of climate change, finite resources and unevenly distributed wealth. They address a variety of rather broad but also concrete targets for different time scales. Partly they are not binding and therefore cannot be taken as the most probable evolution. Moreover, it is expected that macroeconomic and technological developments will continue to shape the future, as they did in the past, at least in the medium and long term.

In brief, whilst advances in science and evolving policy formulation sketch possible directions, the degree of uncertainty about the state of the world in the coming decades remains significant. Indeed, expectations within a medium-term future, such as 2030, range between a 'perfect storm' scenario (Beddington, 2009 and 2015) and optimistic visions or foresights of an environmentally and socially sustainable Europe with green technology-driven growth (IFOAM, 2015).

During and in the aftermath of the 2007/8 food crisis many policy makers and research institutions were alerted and painted a picture of almost insurmountable challenges. The UK scientific advisor at that time, John Beddington, argued that by 2030 the preconditions for a 'perfect storm' could be provided: the world's population rising from 6 billion to 8 billion (33%); demand for food increasing by 50%; demand for water and energy increasing by 30% and 50% respectively (Beddington, 2009 and 2015). Revisiting the situation in 2015, the picture is multifaceted. As a matter of fact, the 2015 Revision of World Population Prospects projects the world's population to reach 8.5 billion by 2030, an important increase compared to earlier projections (United Nations, 2015a). Yet, global food prices, the indicator for the balance of supply and demand, have declined since 2013 and the newest projections of OECD/FAO for the next decade foresee real prices to resume their long-term secular decline (OECD-FAO, 2015). Climate change adds a further layer of complexity. A recent study by the USDA identifies poor populations and tropical regions as most prone to climate risks to food security; temperate regions on the other hand could even gain, at least in the medium term (USDA, 2015).

These considerations point to agriculture with its key role in linking many of the above challenges, primarily to satisfy the fundamental human need to obtain sufficient and nutritious food. Agricultural production, based on the use of natural resources, both infinite (sun light) and finite (land, water, fossil fuels), implies reciprocal effects on land and from climate/weather. As the use of agricultural products also extends toward industrial processes and energy generation, these latter activities have tangible impacts on the agrifood system. Together with forestry and fishery, these sectors comprise the so-called bioeconomy.

The present study aims to combine the existing knowledge on economic, societal and political trends related to the bioeconomy sectors in a systematic and interconnected way, in order to create a plausible reference scenario for 2030, also called a business as usual (BaU) or reference scenario (RS). The RS, while focussing on Europe does not ignore the dynamics in other parts of the world and allows projecting the development of the European bioeconomy under a status-quo policy development. In a second step two scenarios are developed and compared to illustrate the complexity and consequences of decision-making targeted to turn challenges into concrete roadmaps towards specific visions.

[1] Tackling climate change through a new international agreement on emissions, applicable to all countries, is the aim of the United Nations Framework Convention on Climate Change. Progress in this conference at the end of 2015 is seen as a crucial achievement to keep global warming below 2°C (http://www.cop21.gouv.fr/en).

1.2 Related European policy initiatives

As a significant political and economic player on the world stage, the EU has taken a pro-active role in areas relating to GHG emissions reductions and renewable energy usage as well as the greening of its agricultural policy . More recently, in 2012, a policy strategy paper was released by the European Commission (EC) for a sustainable model of growth which could reconcile the goals of continued wealth generation and employment with sustainable resource usage (EC, 2012). To this end, the term 'bioeconomy' was coined which, "encompasses the 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, p.3). Under this definition, one is led to understand that bio-based output not only includes obvious examples such as agricultural and food output, but can be extended to embrace any additional value added activities which employ organic matter of biological origin (i.e., non-fossil) which is available on a biologically renewable basis (e.g., plants, wood, residues, animal and municipal wastes, fibres etc.).

Part of the EU's Bioeconomy Strategy (EC, 2012) is to stimulate research and development activities which can identify and enhance knowledge of bioeconomic resources and develop forward-looking policy recommendations to meet these aforementioned, and in many cases, conflicting, challenges. 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 in times of post-crisis. Thus, the key challenge is one of policy coherence to tackle such a broad range of objectives. The European Commission committed itself to an improved biomass policy which would, amongst other things, allow for fair competition between different biomass uses. In particular, it is stated that, "An improved biomass policy will also be necessary to maximise the resource efficient use of biomass in order to deliver robust and verifiable greenhouse gas savings and to allow for fair competition between the various uses of biomass resources in the construction sector, paper and pulp industries and biochemical and energy production. This should also encompass the sustainable use of land, the sustainable management of forests in line with the EU's forest strategy and address indirect land use effects as with biofuels." (EC, 2014, p.7).

Moreover, European agrifood policy-making sees in the bioeconomy "a unique perspective to address the multidimensional challenges of food & energy security, climate change, environmental protection & industrial renewal" (European Council, 2015, p. 2).

The improvement of biomass supply and use efficiency is also envisaged in the Circular Economy Package adopted by the European Commission in December 2015. It includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which should boost global competitiveness, foster sustainable economic growth and generate new jobs (EC, 2015a).

[2] See f.ex. Renewable Energy Directive 2009/28/EC(RED), Energy Roadmap2050 (COM(2011)885), 2030 Climate and Energy Policy Framework (European Council,2014).

[3] See, The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future (COM(2010)672 final); also the EU Forest Strategy for forests and the forest-based sector ((COM(2013)659 final).

[4] A very exhaustive overview on the definitions and the related policy initiatives is provided for instance by Scarlat et al. (2015).

1.3 From foresight to scenario analysis

A wide range of studies, many of them more qualitative oriented, describe different possible futures of Europe (and the world) and define broad steps on how to reach a particular vision. The present chapter does not provide an exhaustive literature review, but rather examines the scenario design of recent studies with a 2030+ horizon and their potential usefulness for the current study.

The foresight report **Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe** (EC, 2015b) explores the interactions between the primary sectors and the broader bioeconomy. Describing in detail the state of play in the bioeconomy, the report discusses the key trends and policies influencing the bioeconomy sectors. Scenarios are presented of what might happen by developing the paradigm of the bioeconomy, within the fundamental constraint of sustainability. These scenarios, called BIO-MODESTY, BIO-BOOM, and BIO-SCARCITY, are defined by alternative futures of two main uncertainties, which are demand growth for biomass for materials and energy, and supply growth of biomass. Under the condition of the simultaneous achievement of the bioeconomy goals and implemented according to the principles - food first, sustainable yields, cascading approach, circularity and diversity – the report concludes with a list of most pertinent research themes.

The foresight exercise **Global Food Security 2030 Assessing trends with a view to guiding future EU policies** was published in June 2015 (Maggio et al., 2015). It comes to the conclusion that: “By 2030 and beyond, food security will increasingly be considered as securing food supply in response to changing and growing global demand. Food security is not only a global and systemic challenge, but also an opportunity for the EU to play a role in innovation, trade, health, wealth generation and geopolitics. Better coordination and coherence at EU level are necessary in order to move from a food-security to a food-systems approach”. The report stresses the importance of the Policy Coherence for Development (PCD) approach in the EU, which seeks to minimise inconsistencies and build synergies between all relevant policies apart from development cooperation. These policies include agriculture, trade, research and development, innovation, biodiversity, land use and the impact of bioenergy production, and fisheries policy. Experts developed a vision for 2030 which foresees a significant reduction in the relative number of undernourished people and food security being guaranteed on a sustainable basis.

The **FP7 project VOLANTE (Visions of Land Use Transitions in Europe)** proposes a set of pathways under a suite of scenarios to arrive at visions of land use. Land as such has no policy, but as agriculture’s key production

factor, land is directly influenced by the CAP and various other policies such as environment, climate and trade policies. In the context of BioEconomy2030, the scenarios and the systematic identification of trade-offs are of relevance (Verkerk et al., 2014). Having involved a multi-disciplinary team of researchers and stakeholders, four marker scenarios are chosen, based on modified Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES):

- A1: Globalized world with strong economic growth and weak intervention. The EU's CAP is fully abolished.
- A2: Fragmented world with modest economic growth and weak intervention. The CAP remains unchanged.
- B1: Globalised world with modest economic growth and strong intervention. The CAP is fully abolished.
- B2: Fragmented world with modest economic growth and strong intervention. EU CAP remains unchanged.

Although a reference scenario (baseline) is not generated, the approach and methodology have similarities with the BioEconomy2030 study since it also uses a CGE model to enumerate outcomes.

FOODSECURE is an interdisciplinary research project with the objective of designing effective and sustainable strategies for assessing and addressing the challenges of food and nutrition security. Stakeholder scenario development workshops have been an important element to develop a plausible set of qualitative scenario narratives towards the year 2050, as well as desired outcomes and options for measures (Kuiper et al., 2015). Distinguishing antagonistic orientations of equality and sustainability, and revisiting the SSP framework, four scenarios are developed:

- 1% world: In 2050, the investment in technology, innovation, mitigation and ecosystem services continues in order to safeguard the benefits for "the new rich" (1% of the population), which at the same time leads to a very sustainable world in a very unequal setting.
- Ecotopia: In 2050 in this world there will be a sustainable diet for everybody, including full access to a diversity of food choices. The central narrative in this scenario is a technological revolution supported also by positive policy incentives to food and nutrition security and a shift in international frameworks.
- Food for all but not forever: In this world, economic growth, regardless of the costs to the environment, has led to a shared wealth among all. However, at the end of the period towards 2015, the natural systems are on the verge of collapse around the world, including increasing climate-induced natural disasters.
- Too little, too late: This scenario perpetuates inequalities in material gains, as well as in opportunities and services. The gap between the "haves" and the "have nots" continues to widen. Poor governance, mismanagement and uncontrolled depletion of natural resources are complicated by the succession of natural man-made disasters and further undermine the food and nutrition situation, mainly for the masses.

At the time of writing, the results of the FOODSECURE scenarios have yet to be published.

As a global benchmark, the **Agricultural Model Intercomparison and Improvement Project** (AgMIP) (von Lampe et al., 2014) considers a range of scenarios or narratives projecting up to 2050 with the objective of identifying how variation in the underlying macroeconomic, technological and biophysical drivers under different future pathways lead to differing market developments in the long-run (2050) and very long (2100). In addition to variations of scenarios and assumption, several global economic models were run and compared to improve the understanding of the reasons for different or even contradictory simulation outcomes. The paper emphasises among others the need for careful analysis of the model variables (in particular when comparing across models), which is addressed in this study by means of a thorough analysis of the drivers. The AGMIP project, with its variety of Partial Equilibrium (PE) and CGE models, confirms a priori expectations that CGE models generally show "smoother" price paths, i.e. lower price increases or decreases in the reference scenario, and smaller price changes relative to alternative assumptions on exogenous drivers (von Lampe et al., 2014).

Since the current research focus is on the influence of government policy rather than projections, the experiments in the current study borrow AgMIP reference scenario estimates of real GDP growth and population characteristic of the Shared Socioeconomic Pathway 2 (SSP2), the so-called "middle of the road" projections. Largely following past trends, "In SSP2, global population reaches 9.3 billion by 2050, an increase of 35% from 2010. Population growth slows significantly over time and shows large differences across countries. Global GDP triples between 2010 and 2050, more rapidly during the first half of that period than after 2030. Growth in most "Organisation for Economic Co-operation and Development (OECD) countries is assumed to be moderate, while GDP in a number of developing countries is assumed to grow more than 10-fold." (von Lampe et al., 2014, p. 7). These assumptions reflect a status quo vision of the world and are assumed common to each of the policy narratives in the current study.

The aforementioned studies have inspired the conception and implementation of the present research project. The choice of a global economic model is motivated by the strong dependence of the main biomass provider, the agrifood sector, and its influencing policies on the future development of the global economy. Employing a state-of-the-art multi-region market simulation model and database, the aim of this research is to further build on existing research which has attempted to tackle some of the challenging questions at a global scale (von Lampe et al., 2014), in three ways. Firstly, it complements the broader global view provided by previous initiatives with a detailed one for the EU, with some focus at the member state level. Secondly, different narratives or story lines are developed which reflect different philosophical outlooks resulting from government policy (as opposed to different assumptions pertaining to macroeconomic growth, technological change and biophysical constraints). As a result, this research sets its gaze more firmly on a more medium term future, rather than 'blue sky' research initiatives which examine the inherent uncertainty which is characteristic of long and very long run time horizons.

Finally, the scope of bio-based activities goes beyond the standard definitions inherent within national accounts data to encompass sources of biomass supply, biofuels and biochemicals, whilst also taking account of 'new' technologies (i.e. second generation fuels) which, hitherto, are still in their infancy but may be expected to play a key role in shaping the bioeconomy in the medium term.

The authors decided to define a limited number of scenarios to keep the analysis and the reader focussed on the key messages. From a pragmatic perspective, it is recognised that fully coherent future oriented storylines cannot exist in a world with a non-coherent historical development and numerous uncertainties. As a result, to illustrate the trade-offs among different potential orientations and developments, the characterisation of future pathways is restricted to a series of main drivers of an 'external' (technological development, oil price) and 'internal' (mainly policies influencing the agrifood and bio-based sectors) nature. The two narratives chosen are inspired by the above cited studies, which have conceptualised scenarios and visions through a comprehensive process of expert and stakeholder interaction:

Outward looking, where EU policy actively pursues an innovative and sustainable model of employment and growth promoting the concept of the bioeconomy.

Inward looking, where the EU takes a ‘tried and tested’ approach toward employment and growth.

The scenarios/visions are mainly distinguished through the degree of connection to global markets and sustainability orientation. In the current study, both visions are conditioned by internal policies, i.e. policies (principally European) related to trade, agriculture, environment, climate change and bioenergy.

In addition to the limits on creating fully coherent storylines and scenarios, the model implementation also has its restrictions. A comprehensive and integrative systems approach, as for example suggested in the final recommendations of the EXPO 2015 (Fischler et al., 2015), is certainly desirable and can be approached in large-scale research exercises. The present study delivers a more restricted, but traceable and methodologically sound approach. Where appropriate, a degree of sensitivity analysis has been carried out to identify the magnitude of the variables impacting the results.

The initial concept and preliminary results were presented and discussed in academic and policy circles (M’barek et al, 2015). The feedback received served as a useful springboard to further develop the approach.

The structure of this report is as follows: Chapter two describes the data and model framework employed for this study. Chapter three outlines the experimental implementation of the study (i.e., data aggregation, modelling assumptions, scenario design etc.). Chapter four presents the reference scenario results, whilst chapter five examines the resilience of EU bioeconomic sectors by comparing the results of two alternative policy visions with those of the reference scenario. Chapter six provides some final observations, caveats and future developments.


Analysis

2 DATA AND MODEL DESCRIPTION

This chapter introduces the database and the methodology employed to perform this study. A fully consistent and academically recognised global database, based on contributions from members of the Global Trade Analysis Project (GTAP) network is the main database employed.

The economic model used is a state-of-the-art neoclassical multi-region computable general equilibrium (CGE) model known as the Modular Applied GeNeral Equilibrium Tool (MAGNET). A key strength of the MAGNET model is that it allows the user to choose a la carte those sub-modules of relevance to the study at hand. In the context of the current study, MAGNET captures the specificities of bio-based, agricultural, and energy markets.

2.1 Extended GTAP database

The GTAP database (Aguiar et al. 2012) contains a complete record of all economic activity (i.e., production, trade, primary factor usage, final and input demands, taxes and trade tariffs and transport margins) for 57 activities and 140 regions. In the standard version of the GTAP database, the definition of bio-based activity is confined to eight cropping and four livestock activities; eight processed food and beverages sectors, fishing, forestry, textiles, wearing apparel, leather, wood and paper products. Additional sources of bio-based activity (e.g., bioenergy, biochemicals) are subsumed within aggregated parent industries.

In the first instance, this report takes advantage of earlier work (Banse et al., 2008) on first generation biodiesel and bioethanol production and associated by-products (oilcake, dried distillers grains with solubles - DDGS) which are used as feeds in animal production systems. More recently, based on LEI (2014) and Van Meijl (2016), version 8.1 of the GTAP data has been further extended to explicitly represent sources of biomass supply (i.e., residues, plantations and pellets), second generation biofuels based on thermal and biochemical technologies, bioelectricity and biochemical activities.

A recent inventory of current employment and wealth generation in the EU bio-based industry was undertaken by the Nova Institute (2014). In their report, explicit reference is made to the classification of bio-based sectors given as follows: agriculture; food, beverages and tobacco; forestry; fishing; paper and paper products; wood and wood products; textiles; biofuels and biochemicals. To capture this diverse range of bio-based commodities, 49 tradable goods are disaggregated from the modified GTAP database, of which 39 are bio-based (**see Table 1**).

TABLE 1
GTAP data aggregation

SECTORAL DISAGGREGATION (49 commodities):

- **PRIMARY AGRICULTURE** (10 commodities): wheat (wht); other grains (grain); oilseeds (oils); raw sugar (sug); vegetables, fruits and nuts (hort); other crops (crops); cattle and sheep (cattle); pigs and poultry (pigpoul); raw milk (milk); crude vegetable oil (cvol).
- **FOOD AND BEVERAGES** (5 commodities): meat (meat); dairy (dairy); sugar processing (sugar); vegetable oils and fats (vol); other food and beverages (ofdbv).
- **OTHER 'TRADITIONAL' BIO-BASED ACTIVITIES** (7 Commodities): fishing (fish); forestry (frs); textiles (tex); wearing apparel (weapp); leather products (leath); wood products (wood); paper products and publishing (ppp).
- **BIOECONOMY SUPPLY** (5 commodities): plantations (plan); residue processing (res); pellets (pel); agricultural residues (r_agric); forestry residues (r_frs).
- **BIO-BASED ENERGY** (5 commodities): 1st generation biodiesel (biod); 1st generation bioethanol (biog); bioelectricity (bioe); 2nd generation thermal technology biofuel (ft_fuel); 2nd generation biochemical technology biofuel (eth).
- **BIO-BASED CHEMICALS** (4 commodities): lignocelluose sugar (lsug); polylactic acid (pla); polyethylene (pe); mixed bio/fossil chemicals (f_chem).
- **BIO-BASED AND NON BIO-BASED ANIMAL FEEDS** (3 commodities): bioethanol by-product distillers dried grains and solubles (ddgs); biodiesel by-product oilcake (oilcake); animal feed (feed).
- **FERTILISER** (1 commodity): fertiliser (fert).
- **FOSSIL FUELS AND ENERGY** (6 commodities): crude oil (c_oil); petroleum (petro); gas (gas); gas distribution (gas_dist); coal (coa); electricity (ely).
- **OTHER SECTORS** (3 commodities): chemicals, rubber and plastics (crp); transport (trans); other sectors (OthSec).

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).

To maintain the model within manageable proportions, the regional disaggregation is limited to 23 regions. As a prospective study focusing on market developments in the EU, with some detail at member state level, a number of EU countries are disaggregated. The selection criteria incorporates larger EU members (i.e., France, Germany, Italy, Spain, UK) whilst the specific choice of Ireland and Poland reflects the relative importance of bioeconomy activity (primarily, agriculture) in these countries. In addition, EU member state disaggregation reflected more pragmatic modelling considerations, to allow for the correct budgetary allocation to those countries which receive special dispensation under the CAP budget rebate. The remaining EU27 countries are aggregated together. Lastly, as the 28th EU member state from July 1st, 2013, Croatia is treated separately to allow for its explicit inclusion within the single market (via exogenous tariff rate adjustments) and the 'own resources' of the CAP budget mechanism. In the non-EU regions, 'large players' (both net exporters and importers) on world agrifood markets are identified (see Table 1), whilst to examine the possible impacts on impoverished partners, both the Middle East and North Africa (MENA), and Sub-Saharan African (SSA) regions are represented. All residual trade and output flows are captured within a Rest of the Word (ROW) region.

2.2 MAGNET model

To enumerate forward looking economy-wide policy analysis, this study turns to a class of CGE mathematical market simulation models, consisting of a system of three types of equations. Firstly, behavioural equations employing 'convenient' mathematical functions represent, under conditions of constrained optimisation, the theoretical tenets of neoclassical economic demand and supply. Subject to a series of market clearing (i.e., supply equals demand) and accounting equations (i.e., income equals expenditure equals output; zero economic profits) consistent with the underlying accounting conventions of the database, the model enforces 'equilibrium'. To solve the model, the number of equations and (endogenous) variables within the system must be equal (known as the model 'closure'). Additional variables under the direct control of the modeller (defined as 'exogenous'), which typically capture market imperfections (tax rates), factor endowments or technological change, can be manipulated or 'shocked', whereupon the model finds a new matrix of prices and quantities to arrive at a post-shock equilibrium subject to the aforementioned accounting and market clearing restrictions.

This study employs a state-of-the-art neoclassical multi-region CGE model known as MAGNET. A key strength of the MAGNET model is that it allows the user to choose a la carte those sub-modules of relevance to the study at hand. In the context of the current study, this incarnation of MAGNET captures the specificities of bio-based agricultural and energy markets. To characterise the peculiarities of agricultural markets, modelling code accounts for the heterogeneity of land usage by agricultural activity; a regional endogenous land supply function; the immobility of capital and labour transfer between agricultural and non-agricultural sectors with associated wage and rent differentials; the inclusion of explicit substitution possibilities between different feed inputs in the livestock sectors; and additional behavioural and accounting equations to characterise EU agricultural policy mechanisms (i.e., production quotas, single farm payment, Pillar 2 payments). In the case of 'first' and 'second' generation biofuels, the model code follows the work of Banse et al., (2008) by including blending targets which can be activated to reach pre-designated policy mandates.

Further modelling enhancements are incorporated to the (i) CAP module (Boulanger and Philippidis, 2015)

[5] The Netherlands and Sweden are grouped together since their modelling treatment within the own resources mechanism of the CAP budget is identical (see Boulanger and Philippidis, 2015).

[6] MAGNET is part of the integrated Modelling Platform for Agro-economic Commodity and Policy Analysis (iMAP) hosted by the European Commission's Joint Research Centre, Institute for Prospective Technological Studies (M'barek et al., 2012). For a fuller description of the MAG-NET model see Woltjer and Kuiper (2014).

and the (ii) GHG and emissions taxes module. For the CAP module, additional coupled and decoupled Pillar 1 policy variables are included to allow or a finer representation of CAP policy shocks. These variables link the CAP accounting equations with the standard GTAP data tax wedges. Furthermore, a detailed set of CAP policy payments, taken from the Clearance of Accounts Audit Trail System (CATS) database (DG AGRI) are used as a

basis for calculating 'CAP reference scenario' shocks. In addition, an 'own-resources' module is included within the CAP budget accounting equations. For the GHG module, a series of carbon tax variables are inserted into the model code. Thus, endogenous changes in carbon taxes ensure that price signals combined with assumptions of input substitutability determine the input and output changes consistent with the exogenous changes in GHG emissions. This version of the model does not take into account a more detailed picture of climate policies such as the inclusion of differentiation between sectors belonging to the EU Emissions Trading System (EU ETS) and non-ETS sectors, auctioning in the power sector and renewable energy targets as laid out in the 2030 Framework for Climate and Energy policies (EC, 2014).

In terms of the model closure, all primary factor endowments (except land) and policy variables (ad valorem taxes and tariffs) are assumed exogenous. In neoclassical CGE models, technical change is traditionally treated as exogenous, although output- and input-augmenting technical changes in relation to Pillar 2 expenditures are treated endogenously (Woltjer and Kuiper, 2014). To ensure macro closure, withdrawals (savings (S), imports (M) and CAP contributions (CC)) must equal injections (investment (I), exports (X) and CAP receipts (CR)). Under conditions of fixed savings rates and steady state investment behaviour, as well as marginal changes in net CAP budget contributions (i.e., CC – CR) by member states, the trade balance adjusts to ensure a fully closed macroeconomic circular flow.

In the case of the labour market, one is effectively assuming that the participation rate of the workforce remains unchanged, which at the same time is theoretically consistent with a medium to longer term assumption of a fixed 'natural rate of unemployment'. This assumption should be made clear when examining the results reported for the changes in bioeconomy employment (see sections 4.5 and 5.1.3) changes in the number of people

[7] In the non-EU regions, both CR and CC are zero.

employed. In other words, with total labour supply invariant between competing scenarios, there is no possibility that, for example, a potentially detrimental scenario for country 'x' could lead to a shrinking of the national labour force. As a result, with no shedding of labour in country 'x', the CGE analysis would tend to exaggerate wage rate falls.

As an additional tool of analysis, this study draws on the use of a decomposition method known as 'subtotals' based on the pioneering work of Harrison et al (2000). More specifically, on running a complex scenario with an array of shocks (i.e., endowments, tariffs, technology change etc.), it is possible to calculate 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 reference scenario, the comparative 'part-worth' importance of the four policy indicators is evaluated in order to better understand the role that policy has to play (if any) in shaping bio-based market trends.

[8] In the short run, alternative treatments could focus on generating a more heterogeneous characterisation of labour supply by skill type accounting for the well-known 'labour-leisure' trade-off. A 'short run' endogenous treatment of changes in labour participation rates and total employment consistent with the MAGNET model is discussed in Shutes (2013). Employing a calibrated upward sloping supply curve and asymptote, the treatment of the labour-leisure choice is implicit, rather than explicitly modelled.

[9] Employing the terminology of Harrison et al. (2000), for a simplistic function Z=F(X,Y), where Z is endogenous and X and Y are exogenous, GEMPACK calculates the change in the separate values of the first derivatives corresponding to X and Y within the total derivative dZ, accumulated over all the steps specified within the model algorithm. Furthermore, the part-worths of each exogenous variable are calculated based on the GEMPACK assumption that the rate of progression in the set of exogenous shocks along the path is proportionally linear.

[10] It is expected that as a direct consequence of changes in exogenous policy shocks, their respective part-worths will change compared with the reference scenario. What is perhaps less obvious is that when changing the policy conditions of the experiment, the deviation in the solution path of the model from the reference scenario can also alter the part-worths of unchanged exogenous shocks (i.e., projections and fossil fuel world prices). For example, steeper greenhouse gas cuts in the EU in the OL scenario will affect the entire macro-economy, which implies additional impacts on (inter alia) factor prices. Thus, the set of unchanged projections shocks, with a different vector of factor prices, will also now have a different part-worth.

3 REFERENCE SCENARIO AND SCENARIO IMPLEMENTATION

In attempting to understand the impacts of different policy options on potential market developments across a diverse portfolio of bioeconomic activities (agrifood and bio-based), it is necessary to carefully design a reference scenario which constitutes a status quo policy representation. Indeed, an envisaged objective of the current research project is to look at market developments based on current and 'foreseeable' policy driven challenges within a more immediate time frame. Thus, 2030 is chosen as the end period for our experiments. In the reference scenario, there is no deviation from existing policy thinking.

Then, as a departure from the reference scenario, two further contrasting policy visions are represented in the 2020-2030 period, an inward-looking and an outward-looking policy narrative.

3.1 Reference Scenario

3.2 Scenarios

3.1 Reference Scenario

As explained in the introduction, the **projections** of developments in **real GDP growth** and **population characteristic** follow the AGMIP project reference scenario, based on the SSP2: "In SSP2, global population reaches 9.3 billion by 2050, an increase of 35% from 2010. Population growth slows significantly over time and shows large differences across countries. Global GDP triples between 2010 and 2050, more rapidly during the first half of that period than after 2030. Growth in most OECD countries is assumed to be moderate, while GDP in a number of developing countries is assumed to grow more than 10-fold." (von Lampe et al., 2014, p. 7). These assumptions reflect a status quo vision of the world and are assumed common to each of the policy narratives in the current study. The details of the assumptions on macroeconomic and population development as well as relevant policies can be found in table 2 and table 3.

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Trade policy shocks are focused on the EU's existing or foreseeable free trade agreement (FTA) commitments within the 2007-2020 time horizon. These are characterised employing tariff elimination shocks, whilst no non-

TABLE 2
Real GDP and population shocks consistent with SSP2

	2007-2013 POPULATION	2007-2013 GDP	2013-2020 POPULATION	2013-2020 GDP	2020-2030 POPULATION	2020-2030 GDP
UNITED KINGDOM	4.00	0.46	4.54	17.83	5.78	21.07
NETHERLANDS & SWEDEN	3.20	5.53	3.88	15.32	5.18	19.19
DENMARK	2.87	-1.77	3.20	13.06	4.84	14.94
GERMANY	-0.38	4.75	-0.35	10.14	-0.67	9.85
AUSTRIA	2.32	6.47	2.28	14.00	2.87	15.99
FRANCE	3.64	1.99	4.16	12.47	5.59	19.58
IRELAND	8.38	-5.37	8.30	18.77	9.46	24.04
ITALY	2.83	-3.99	0.85	8.14	0.41	13.02
SPAIN	5.80	-0.18	3.34	8.94	2.95	12.78
POLAND	0.43	21.92	0.14	23.77	-1.36	25.78
REST EU27	0.46	0.84	0.16	15.90	-0.17	23.61
CROATIA	-0.92	-3.88	-1.05	13.20	-1.84	17.18
USA	5.14	5.51	5.64	22.25	7.53	23.09
CANADA	6.48	7.95	7.54	19.29	9.58	21.53
MERCOSUR	5.86	24.54	5.90	29.31	6.46	35.29
RUSSIA	-0.33	13.66	-0.60	29.56	-1.65	35.98
CHINA	2.54	71.05	1.79	72.72	0.10	64.81
INDIA	8.59	51.82	8.89	57.37	10.12	75.10
JAPAN	-0.13	0.63	-1.22	7.51	-3.53	10.27
AUSTRALIA & NEW ZEALAND	10.08	15.89	10.50	25.45	12.98	28.37
MENA	11.72	26.22	11.42	37.54	13.01	46.27
SSA	15.72	31.25	17.23	46.85	22.22	68.37
ROW	6.98	20.95	7.33	33.00	8.31	41.54

Source: authors' own calculation

tariff measures (NTMs) are considered. The tariff shocks for those FTA agreements which straddle more than one time period are assumed to be implemented in a time linear fashion. Further potential multilateral (i.e., Doha) and bilateral (i.e., USA, Mercosur, Japan, etc.) trade agreements are not contemplated due to the uncertainty of a firm timetable for agreement.

In terms of **agricultural policy**, the 2007-2013 period incorporates detailed sector and region specific Pillar 1 and 2 actual (vis-à-vis, planned) expenditures up to 2011 taken from the CATS database. It should be noted that Pillar 1 Single Farm Payments (SFP) and Single Payment Scheme (SPS) payments are assumed to be completely decoupled from production. Thus, these payments are only made on the land factor. Pillar 2 payments are aggregated to the five categories employed within the MAGNET model ('agri-environmental schemes'; 'least favoured areas'; 'physical capital'; 'human capital' and 'wider rural development'). Given the 'co-financed' nature of Pillar 2 support between EU and individual member state budgets, policy shocks to national government Pillar 2 spending are also implemented in the first period based on the CATS data. In the 2013-2020 period, it is assumed that the structure of Pillar 1 payments (decoupled/coupled), Pillar 2 co-finance rates and the distribution of Pillar 2 expenditures in member states remain the same at the end of the first period. Payment totals for Croatia in the second period are taken from the European Commission (2009), whilst exogenous spending limits for the CAP budget over the 2014-2020 Multiannual Financial Framework (MFF) are taken from the European Commission (2011). Finally, in light of recent CAP reforms, the 'greening' of 30% of Pillar 1 decoupled payments is modelled by characterising them in an identical fashion to Pillar 2 agri-environmental payments.

To characterise **EU bioenergy policy**, by the end of the first period (2007-2013), in the absence of detailed member state data, it is assumed that the 'first generation' 5.75% blending target on transport fuel usage set for 2010 (which was missed), is met uniformly by all member state, by 2013. In the case of Germany, the benchmark data reveals a blending share of above 7%. This is consistent with actual data, although Germany's blending mix slipped back to 5.5% by 2009 due to changes in German tax policy (i.e., reduced incentives to blenders). Thus, in the first period, Germany's blending target is left endogenous. In the second period (2013-2020), a blending mandate of 7% is imposed on all EU member states for first generation biofuels based on projections by Hamje et al., (2014). For second generation biofuels, a blending limit of 1.5% is assumed within the 2013-2020 period. Following Banse et al. (2008), in all EU regions and in all time periods, bioenergy policy is assumed to be fiscally neutral (i.e., subsidies to blenders are paid for by taxes on final users).

Environmental policy is characterised by implementing historical and projected exogenous GHG emissions
.Pg 40 reductions in each of the regions (Table 4), taken from an energy and emissions focused variant of a CGE global model (Labat et al., 2015). In this study, the GHG emissions shocks are implemented 'tops-down' by regions, such that the model endogenously determines the allocation of emissions reductions by sectors to meet the region-wide restriction. In the case of the EU, the emissions shock is imposed for the entire EU28 trade bloc. This implies that an emissions burden sharing scheme is in force, not only between the member states, but also between production activities to meet exogenous emissions targets.

In the case of the EU28, the emissions reductions implemented between 2007 and 2020 are consistent with the EU's 2020 Climate and Energy Package. More specifically, the imposed shocks are taken from a 'baseline'

[11] The study does not consider sensitive tariff line exceptions for each of the EU's bilateral free trade area agreements since it is not envisaged that the inclusion of such exceptions with 'small' trading partners within the scenario design will affect model results.
[12] In future research endeavours of this nature, this data could be updated and even extended to a longer time series for more flexibility.

TABLE 3
Assumptions shaping the 'status quo' reference scenario (2007-2013-2020)

(2007-2013 PERIOD)

PROJECTIONS
- Skilled and unskilled labour, capital, natural resources, population, and macro growth (SSP2).

TRADE POLICY
- Non reciprocal EU27 tariff eliminations with the Everything But Arms countries.
- Removal of any remaining tariffs between Mexico and the EU27 (agreement enacted in 2000).
- 30% applied tariff reductions between South Korea and the EU27 (agreement enacted in 2010).
- 20% applied tariff reductions between Peru/Columbia and the EU27 (agreement enacted in 2011).

AGRICULTURAL POLICY (INCLUDING 2008 HEALTH CHECK REFORMS)
- Phasing in of decoupled payments for 2004 and 2007 accession members.
- Targeted removal of specific Pillar 1 coupled support payments: Arable crops, olives and hops to be fully decoupled from 2010; Seeds, beef and veal payments (except the suckler cow premium) decoupled by 2012, Protein crops, rice and nuts will be decoupled by 1 January 2012, Abolish the energy crop premium in 2010.
- Re-coupling of support under the article 68 provision: Member states may use up to 10 per cent of their financial ceiling to grant measures to address disadvantages for farmers in certain regions specialising in dairy, beef, goat and sheep meat, and rice farming.
- Pillar 2 payments to the EU27 under the financial framework.
- Cumulative shocks for milk quotas rise of 1 per cent annually from 2009 to 2013.
- Projected reduction in CAP expenditure share of the EU budget.
- Change in Swedish and Dutch lump sum rebates corresponding to CAP expenditure share of EU budget.

BIOFUELS POLICY
- EU27-wide 1st generation biofuel mandate of 5.75%.

ENVIRONMENTAL POLICY
- Greenhouse gas emissions reductions consistent with status quo projections.

FOSSIL FUEL PRICES
- Impose historical changes in world prices for coal, gas and crude oil.

(2013-2020 PERIOD)

PROJECTIONS

- Skilled and unskilled labour, capital, natural resources, population, and real GDP (SSP2).

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% 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

- Greenhouse gas emissions reductions consistent with business as usual projections.

FOSSIL FUEL PRICES

- Impose projections of expected changes in world prices for coal, gas and crude oil.

scenario within Labat et al., (2015) study, where EU and global emissions reflect, "the effects of the current pre-2020 mitigation pledges on global emission levels up to 2050, without new additional policies by 2020 or beyond.... In this reference scenario scenario, global emissions would increase ...by more than 10% above 2010 levels by 2020 and by at least 30% above 2010 levels by 2030" (Labat et al., 2015, pp16).

The reference scenario assumes the GHG profile for the EU in 2030 as described in the European Commission Joint Research Centre (2015). Hence, the GHG emissions for this analysis in 2030 are different from and higher than the ones described in the EU energy, transport, and greenhouse gas emissions trends to 2050 of the European Commission (2013). Therefore, this analysis is not fully comparable with the Impact Assessment and related studies in the context of the 2030 Framework for Climate and Energy Policies (EC, 2014).

TABLE 4
Greenhouse gas shocks across time periods and policy narratives

	REFERENCE SCENARIO			INWARD-LOOKING	OUTWARD-LOOKING
	2007-2013	2013-2020	2020-2030	2020-2030	2020-2030
EU28	-7.56	-8.87	-3.33	-3.33	-23.34
USA	-5.13	-6.01	-5.08	-5.08	-5.08
CANADA	-0.85	-0.99	7.07	7.07	7.07
RUSSIA	2.29	2.68	6.38	6.38	6.38
CHINA	28.14	33.54	24.40	24.40	24.40
INDIA	20.58	24.40	32.68	32.68	32.68
JAPAN	-4.50	-5.27	-0.02	-0.02	-0.02
AUSTRALIA & NEW ZEALAND	-1.32	-1.55	9.41	9.41	9.41
ROW	14.38	16.96	23.25	23.25	23.25

Source: authors' own calculation

TABLE 5
World fossil fuel price shocks (World Bank projections)

	2007-2013	2013-2020	2020-2030
COAL	28.64	-11.66	20.48
CRUDE OIL	46.34	-30.92	22.81
GAS	31.20	-7.4	9.30

Source: authors' own calculation

In addition to the projections and policy shocks, **historical and projections shocks to coal, crude oil and gas prices** are also included for all time periods contemplated within this study. In 2007, the coal price was 65.7$ per metric tonne, the oil price was 71.1$ per barrel and the average gas price was $7.7 per million British Thermal Units (BTU). It is anticipated that such shocks will have important repercussions for bioeconomic activity, both as a direct input, but also for the viability of existing (1st generation) and potentially viable (2nd generation) biofuel technologies. The assumptions on fossil fuel prices across all periods are detailed in Table 5. As a strategically important decision variable, subsequent analysis in chapter 4.9 examines the sensitivity of the results with respect to variations in fossil fuel prices.

In the third period (2020-2030) of the study, three possible policy narratives are contemplated.

The reference scenario from 2020-2030 again reflects envisaged projections (SSP2), world fossil fuel prices and policy shocks as above. Thus, finishing shocks on the EU-Canada trade agreement are implemented, whilst no changes are made to real CAP expenditures, although by time-linear extrapolation over the period, it is assumed that the EU budget share corresponding to CAP expenditure continues to decline. The GHG emissions reductions continue to follow the reference scenario path established by Labat et al., (2015). Finally, in the absence of any clear policy beyond 2020, no additional blending mandates in transport fuels for either first or second generation biofuels are imposed between 2020 and 2030, although the existing fiscal support received by the blending industry up to 2020 is maintained fixed in real terms up to 2030.

3.2 Scenarios

As a departure from the reference scenario, two further contrasting policy visions are represented in the 2020-2030 period.

The **inward-looking policy narrative** presents a vision where the EU adopts a 'tried and tested' approach toward employment and growth, with greater emphasis on the promotion of existing carbon technologies, whilst bio-based activity is no longer afforded any policy dispensation. This model of development is facilitated by the decision to not enforce further GHG reductions and abandon the implementation of biofuel mandates. Trade policy embraces the notion of a more inward looking Europe, driven by the forging of alliances with neighbouring countries and strategically important trade partners. As a traditional motor of bio-based growth, EU Agricultural policy remains largely tariff protected from third country imports, although under this policy narrative, EU domestic support policy is firmly rooted in increased market orientation.

[13] By fixing the real value of the blending subsidy, under conditions of continued projections growth, reference scenario biofuel blending targets (now endogenous) will not increase by abnormally high levels.

To capture the spirit of the inward-looking policy narrative, a number of policy shocks are implemented. In addition to the EU-Canada agreement, a neighbourhood and regional tariff policy is pursued by further exogenous tariff elimination shocks. More specifically, the EU forms FTAs with its neighbours, as well as ratifying a Transatlantic Trade and Investment Pact (TTIP) with the USA, although once again, no NTMs shocks are assumed. All Pillar 1 (market support) expenditures are now removed, whilst the biofuel policy mandate and its associated subsidy support is eliminated completely. Finally, GHG emissions follow the same path as the reference scenario. In the 'outward-looking' policy narrative, the EU takes the lead on the world stage. As an example for others to follow, EU policy actively pursues a prototype model of employment and growth which actively promotes the concept of the bioeconomy. There is a policy shift away from carbon based technologies through research and innovation driven bio-based activities, ambitious emissions mitigation measures and higher biofuel blending mandates. In the trade policy arena, the EU (in tandem with others) plays a key role in ratifying a multilateral trade agreement. Although agriculture and other bio-based activities are now more exposed to import competition, this 'greener' vision for EU agricultural policy now prioritises greater provision of environmentally friendly production practises through the substitution of traditional market support (Pillar 1) in favour of rural development initiatives (Pillar 2).

Examining the policy shocks to characterise the outward-looking narrative (Table 6), in addition to the EU-Canada FTA, a multilateral agreement is represented by a stylised 50% reduction in all ad valorem applied tariffs on imports by all countries. The CAP switches expenditures between pillars maintaining budget neutrality, whilst compensating increases in Pillar 2 payments are assumed uniform across each of the five categories. The biofuel mandates are more ambitious, setting a 10% and 5% blending target for first and second generation fuels, respectively.

Finally, the EU unilaterally imposes further emissions reductions consistent with a 'global mitigation scenario' taken from the Labat et al., (2015). This 'global mitigation scenario' scenario contemplates, "global participation by all countries and all sectors (including all) greenhouse gases" (Labat et al., 2015, pp26), yet it also assumes emissions reductions, "according to the countries' capabilities, especially giving time and flexibility to the lowest income countries to join the global mitigation efforts and sustain their growth potentials" (Labat et al., 2015, pp26). Within the current narrative, the focus is to understand the isolated influence of EU led policy initiatives on bio-based market trends. The increased magnitude of the GHG emissions reductions is therefore only applied to the EU (Table 4 - final column), and is consistent with existing EU proposals to further reduce GHG emissions by 43% compared with 1990 levels.

It should be underlined that these scenarios where designed before the agreement reached at the United Nations Climate Change Conferences in Paris (COP 21) between November and December 2015. None of the statements included in the COP21 final agreements have been taken into account within the current scenarios of this study and the ambitious GHG reduction is limited to the EU only.

[14] In the case of environmental policy, the EU has shown much greater willingness to become a global leader, whilst history has shown that in the arena of trade policy, greater reciprocity has always been expected by all developed countries.

TABLE 6
Assumptions shaping alternative policy paths (2020-2030)

REFERENCE SCENARIO (2020-2030 period)

PROJECTIONS
- Skilled and unskilled labour, capital, natural resources, population, and real GDP (SSP2).

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 from EC (2015).

FOSSIL FUEL PRICES
- Impose expected changes in world prices for coal, gas and crude oil.

INWARD LOOKING (2020-2030 period) – reference scenario 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 reference scenario.

OUTWARD LOOKING (2020-2030 period) – reference scenario 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 reference scenario).
- Projected reduction in CAP expenditure shares and lump sum rebates are the same as the reference scenario.
- UK rebate is maintained.

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

ENVIRONMENTAL POLICY
- GHG emissions reductions consistent with 'Global Mitigation' scenario from EC (2015).

4 REFERENCE SCENARIO RESULTS DISCUSSION (2013-2030)

This chapter discusses the output of the reference scenario. Due to the vast number of results generated by the model, the focus of the discussion is largely restricted to EU28 market developments, in particular, those of the traditional and ‘new’ bio-based sectors.

As outlined in the data and model description chapter, this study draws on the use of a decomposition method which allows running a complex scenario with an array of shocks (i.e., endowments, tariffs, technology change etc.) to calculate the part-worth of the resulting endogenous variable change that corresponds to a specific exogenous shock, or pre-specified group of exogenous shocks. In the context of the current study, this is particularly useful for policy analysis, as it reveals the relative weight of each ‘driver’ in shaping the total changes in market trends within a sector. The exogenous drivers are subdivided into (i) projections, (ii) fossil fuel prices, and policy shocks with respect to (iii) the CAP (iv) tariff barriers (v) biofuels mandates and fiscal-neutral support (vi) and GHG limits.

4.1 Real incomes

4.2 EU28 bioeconomy output

4.3 EU28 bioeconomy market prices and world prices

4.4 EU28 energy market prices

4.5 EU bioeconomy employment and wages

4.6 EU land markets

4.7 Trade competitiveness

4.8 Greenhouse gases

4.9 Evaluating the impact of fossil fuel price variations

4.1 Real incomes

Changes in real per capita incomes and equivalent variation are presented for a selection of regions in Table 7. As expected, the majority of the change in per capita real incomes over the period 2013-2030, is driven by the projections shocks. Rising labour and capital endowments increase factor incomes, whilst as a result of the circular flow Keynesian macroeconomic accounting conditions, real GDP growth projections imply rising incomes and expenditures. Examining the fossil fuel prices driver, since 2030 crude oil prices are assumed to remain some way below their levels in 2013 (see Table 5), significant net energy importers (i.e., EU28, USA, China, India, Japan) benefit as a result. On the other hand, net fossil fuel exporters (i.e., Mercosur, Russia, MENA and SSA) witness real income losses under this set of shocks.

From a macroeconomic perspective, the impact of incremental changes in CAP policy is insignificant given the 'small' sector status of agriculture in the EU. With a smaller CAP budget (imposed in the 2013-2020 period), net payers (e.g., UK, Germany) benefit whilst net recipients (e.g., France, Poland, Spain) lose out. In the non-EU regions, the

minor Equivalent Variation (EV) impacts arising from CAP budgetary reform are largely due to changing EU trade demand patterns result from the CAP budgetary real income effect.

The impact of the trade policy shocks is also limited given that EU FTAs with 'small' trading partners plus EU enlargement to include Croatia are unlikely to generate significant trade creation and diversion impacts. In the EU28, the implementation of such FTAs is unequivocally positive – owing to cheaper access to imports and greater exploitation of the EU's comparative advantage.

TABLE 7

Per capita real income and equivalent variation changes (EV in million euros)

	Index 2013=100			Decomposition of index by shocks (2013-2030)						
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	EV (2013-2030)
FRANCE	100	112.5	130.6	30.3	0.8	0.0	0.0	-0.2	-0.4	537,658
GERMANY	100	112.5	124.1	23.4	0.7	0.0	0.0	0.0	-0.1	474,602
ITALY	100	109.2	121.9	21.8	0.6	0.0	0.0	-0.2	-0.3	264,754
POLAND	100	122.4	147.4	47.6	0.8	-0.2	0.0	-0.2	-0.7	154,230
SPAIN	100	108.4	119.1	18.9	0.8	0.0	0.0	-0.2	-0.3	207,170
UK	100	114.9	131.9	31.7	0.2	0.0	0.0	-0.1	0.0	765,162
EU28	100	113.1	128.9	28.5	0.6	0.0	0.0	-0.1	-0.2	3,422,355
USA	100	118.9	136.7	36.2	0.6	0.0	0.0	0.0	-0.1	4,780,824
CANADA	100	111.0	122.7	22.0	0.0	0.0	0.2	0.0	0.5	411,771
MERCOSUR	100	120.2	150.5	49.6	-0.3	0.0	0.0	0.1	1.1	1,016,363
RUSSIA	100	123.7	170.5	70.2	-2.0	0.0	0.0	0.0	2.3	622,940
CHINA	100	163.3	250.7	148.2	0.8	0.0	0.0	0.0	1.7	5,412,350
INDIA	100	146.4	226.8	124.4	1.5	0.0	0.0	0.0	1.0	1,961,166
JAPAN	100	112.5	127.7	27.3	0.6	0.0	0.0	0.0	-0.2	526,949
AUSTRALIA & NEW ZELAND	100	101.2	102.4	2.3	0.0	0.0	0.0	0.0	0.1	403,484
MENA	100	116.1	154.1	55.9	-3.3	0.0	0.0	0.0	1.5	2,065,618
SSA	100	119.4	159.8	59.3	-2.0	0.0	0.0	0.0	2.5	945,585
ROW	100	123.9	158.4	57.0	0.4	0.0	0.0	0.0	0.9	4,062,954

Source: authors' own calculation

[11] The study does not consider sensitive tariff line exceptions for each of the EU's bilateral free trade area agreements since it is not envisaged that the inclusion of such exceptions with 'small' trading partners within the scenario design will affect model results.
[12] In future research endeavours of this nature, this data could be updated and even extended to a longer time series for more flexibility.

The biofuel mandates have a noticeable negative impact for the EU member states, except Germany. Following Banse et al. (2008), the fiscal impact from imposing the mandate is inherently neutral (i.e., subsidies on blended biofuel commodities are funded by taxes on end users). Thus, the main explanation is that with bioeconomy supply bottlenecks from upstream industries, the mandate increases biofuel prices, forces reductions in fossil fuel usage, depresses petroleum output, and therefore, economic growth. With a greater scale of production, the advanced state of blending in the German economy grants it a competitive advantage, whilst to meet the needs of the EU mandate, the resulting increase in third country supplies of biofuels benefits (very slightly) larger scale competitive producers in North America and Mercosur.

Finally, as Table 4 above shows, the path of GHG emissions is assumed to be more restrictive in the EU28, USA and Japan. The economic cost this shock entails (via increases in carbon taxes), by necessity also compromises real income. [15] Those regions facing lesser GHG reductions are granted a competitive edge and benefit at the expense of the EU, USA and Japan.

4.2 EU28 bioeconomy output

In Table 8 the change in EU28 output volumes by sector are presented. The general trend is that non bio-based EU28 activities grow at a relatively faster rate, such that resources are gradually being diverted away from the bioeconomy (see also section 4.5 below on employment). As a collective group, the projections constitute a key motor of growth in all sectors, although the set of exogenous global real GDP shocks (not shown) act as a handicap to EU28 sector growth in a number of bio-based sectors. As EU28 real GDP is assumed to rise at a slower pace than all the non-EU countries, except Japan (see Table 2 in annex), EU trade competitiveness is eroded. This is of particular relevance in the traditional bio-based sectors of textiles, wearing apparel, leather and wood products, and also in fertilisers, where EU self-sufficiency is already lower (i.e., more susceptible to import competition). In other sectors, where the EU self-sufficiency is higher, such as in the aggregate sector 'rest' (includes services, transport, chemicals and some heavy industry), real GDP growth actually motivates sector growth further (not shown). An additional factor is that income elasticities of private demand in wealthier EU countries are generally higher for non-bio-based goods, such that increases in EU real incomes over time further skew demand patterns in favour of these types of products and services (Engel's Law).

In the primary agricultural sector, output remains static over the 2013-2030 period (increase of 1.9 index points), whilst food output rises 12.3 index points over the same period. These results compare with the 31.7 index point increase in EU28 real GDP growth. In part this is due to very low income elasticities on final demands for agricultural products (mostly horticultural crops). In addition, under the assumption of higher land productivities in non EU regions, there is greater import competition in agriculture, leading so a slower growing EU28 agricultural production base. The other significant driver in agriculture is the GHG emissions reduction, which, as noted in section 4.1 above, is assumed to be more stringent for the EU28 (vis-à-vis most other countries). As a relatively more emissions intensive activity, in particular due to its emissions of non CO2 gases (e.g., arising from (inter alia) enteric fermentation, manure management and methane from rice cultivation), the agricultural sector is more acutely affected by this set of shocks. [16] Through its link with input suppliers, the impact of GHG emissions reductions on agriculture also has repercussions on feed and fertiliser sectors, whilst the latter is also affected

[15] Since the EU28 emissions shock is applied 'tops-down', the UK, with a more services based industry, has a less emissions intensive economy than fellow EU member states.

[16] There is no technologically induced change from tightening emissions controls. In agriculture, this is particularly pertinent because many agricultural emissions are modelled as output driven (especially methane emissions in livestock sectors), such that emissions can only be reduced by contractions in output rather than technological substitution in favour of 'cleaner' inputs (see conclusion section 6.4).

TABLE 8
EU28 output volume changes

	Index 2013=100			Decomposition of index by shocks (2013-2030)					
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG
AGRICULTURE	100	100.1	101.9	5.0	0.2	-0.1	0.0	0.3	-3.6
FOOD INDUSTRY	100	104.0	112.3	13.8	0.1	0.0	0.2	0.2	-2.0
FORESTRY	100	103.2	108.8	4.9	0.1	0.0	0.0	1.9	1.9
FISHERY	100	108.5	119.2	16.2	0.5	0.0	0.0	2.3	0.2
TEXTILES	100	88.7	80.7	-18.1	-0.3	0.0	0.0	0.0	-0.9
WEARING APPAREL	100	86.0	76.7	-24.5	0.0	0.0	0.1	0.0	1.1
LEATHER	100	74.8	59.5	-39.5	0.0	0.0	0.1	0.0	-1.0
WOOD	100	96.6	95.3	-7.5	-0.2	0.0	0.0	0.5	2.5
PAPER	100	107.6	118.8	19.4	0.0	0.0	0.0	0.0	-0.6
BIOSUPPLY	100	194.0	216.3	13.9	1.2	0.0	0.0	104.1	-3.1
BIOENERGY	100	157.5	311.9	150.9	20.3	0.1	0.0	47.4	-6.7
BIOCHEMICALS	100	111.3	136.1	61.0	-1.6	1.9	-0.4	-20.4	-4.4
FEED	100	100.8	106.1	14.3	-0.2	0.1	0.2	0.3	-8.7
FERTILISERS	100	79.3	67.8	-0.6	-2.9	-0.1	-0.2	0.8	-29.1
FOSSIL FUEL ENERGY	100	109.1	112.4	14.4	3.3	0.0	0.0	-0.1	-5.3
REST OF ECONOMY	100	113.1	132.0	32.5	0.1	0.0	0.0	-0.1	-0.6
REAL GDP	100	113.3	131.7	131.7	0.2	0.0	0.0	-0.1	-0.2

Source: authors' own calculation

directly since it employs considerable inputs of gas (see also section 4.8). The increase of the overall agricultural output together with a reduction in GHG, is partly explained by the significant increase in oilseeds production steered by the biofuel mandate.

As discussed above, textiles, leather, clothing and wood sectors undergo contractions in output resulting from greater import competition, whilst it is interesting to note that given their status as relatively cleaner sectors, in isolation, the GHG shocks have a much milder, and even positive effect on output in these sectors as resources are diverted from more environmentally prejudicial sectors.

The biomass supply (includes plantations, residues and pellets), bioenergy (1st and 2nd generation biofuels and bioelectricity) and biochemical sectors all record impressive output growth, albeit from a smaller production base. Over the 2013-2030 period, the biochemical sector increases by a factor of 1.36, the output of biomass increases by a factor of 2.16, whilst bioenergy production increases by a factor of 3.12. Examining the impact in these sectors from each set of shocks, the projections are clearly an important driver, although the bioenergy policy mandate and the world price shocks also have a key role to play. The effect of the mandate is especially clear in bioenergy, and by extension, bioeconomy providing sectors (which supply to second generation biofuels, as well as bioelectricity and, to a lesser extent, biochemical production).

Examining the fossil fuel price shocks (particularly crude oil) in isolation, one observes two separate (and conflicting) effects on biofuel production. On the one hand, since biofuels are employed as commodities in the petroleum (blending) sector, the assumed fall in crude oil prices (see Table 5) increases final demands for refined petroleum, which implies greater derived demand for mandated biofuel inputs. On the other hand, in the blending sector there is a direct substitution effect based on the relative price gap between blended bio-based and fossil fuels. In the 2013-2020 period, world fossil fuel prices are assumed to fall slightly more than the general fall in market prices (including biofuels - see next section for price discussion), whilst in the 2020-2030 period, crude oil prices are assumed to rise, in contrast to the continued downward trajectory of general prices. Given the relative price gaps in each period and the technology assumption in the blending sector, the substitution effect away from biofuels in the first period is smaller than the substitution effect in favour of biofuels in the second period, such that over the two periods, world price shocks benefit bioenergy and sectors.

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A more detailed decomposition of agricultural and food sector output changes over the period 2013-2030 for the EU28 is presented in Table 9. For specific agricultural and food activities, the output changes for crops/livestock and food broadly shadow the aggregate sector changes in agriculture and food respectively (see Table 8). The downward trend in the sugar supply chain in the first period is due to the 2017 sugar reform, before some (limited) recovery is recorded in the second period (greater bioethanol demand due to rising crude oil prices). In the three sectors of oilseeds, crude oil and oilcake, significant growth is recorded owing to the EU biofuel policy generating significant bioenergy demand for bioeconomy inputs. [17]

The results in Table 10 focus on the member state output value shares by bio-based activity corresponding to the two years, 2013 and 2030. In general the structural pattern in both periods is very similar (except for bioenergy in Germany – see later). The changes in output value trends are motivated by assumed differences in the rates of real GDP growth. In France, Ireland, Poland and the UK, higher rates of relative growth improve bio-based output value shares in these regions. In contrast, Germany, Italy and Spain which record slower relative macro growth trends face losses in their bioeconomy sector market shares. The single largest change is in the German bioenergy sector, which falls from 35% of EU bioenergy output value in 2013, to 18% in 2030. This is because the German biofuel blending rate was well ahead of other EU regions in 2013, but with an assumed uniform blending mandate in place, other regions 'catch up', thereby eroding the German market share.

[17] In the modified GTAP dataset, a considerable share of oilseeds production is used in the crude vegetable oil 'crushing' sector, which is mainly used in biodiesel (and to a lesser extent food, feed and chemicals).

TABLE 9
Index (2013=100) of output volume changes in EU28 agriculture and food

	2013	2020	2030		2013	2020	2030
WHEAT	100	99.9	100.6	MILK	100	98.7	100.7
GRAINS	100	100.8	101.1	MEAT	100	103.0	106.1
OILSEEDS	100	101.0	127.2	DAIRY	100	102.4	110.8
RAW SUGAR	100	93.9	98.2	SUGAR	100	93.4	93.5
HORTICULTURE	100	100.5	100.2	CRUDE VEGETABLE OIL	100	104.7	163.0
CROPS	100	101.2	102.9	OILCAKE	100	104.5	160.1
CATTLE	100	100.6	99.8	VEGETABLE OIL	100	99.2	99.2
PIGS-POULTRY	100	99.5	98.1	OTHER FOOD	100	105.1	113.5

Source: authors' own calculation

TABLE 10
Member state output value share (%) by bio-based activity

2013	FRANCE	GERMANY	IRELAND	ITALY	POLAND	SPAIN	UK	REST OF EU28
BIOECONOMY	14.5	15.5	1.2	15.7	4.8	8.8	11.3	28.1
AGRIFOOD	16.3	14.8	1.7	13.1	5.2	9.4	11.2	28.2
FORESTRY-FISHERY	17.2	8.8	1.5	7.6	6.5	9.9	7.1	41.5
TEXTILES	11.1	13.0	0.3	31.6	3.0	9.5	9.5	21.9
PAPER-WOOD	12.5	18.1	0.6	14.1	4.8	7.4	12.6	29.8
BIO-SUPPLY	7.1	26.1	0.2	5.1	4.6	3.9	10.0	42.9
BIOENERGY	8.6	34.7	0.7	12.5	3.5	5.9	10.3	23.7
BIOCHEMICALS	14.0	15.8	1.9	8.9	13.8	4.6	8.5	32.4

2030	FRANCE	GERMANY	IRELAND	ITALY	POLAND	SPAIN	UK	REST OF EU28
BIOECONOMY	15.0	14.3	1.3	14.4	5.3	8.4	12.7	28.6
AGRIFOOD	16.8	13.7	1.8	12.7	5.6	9.1	12.2	28.1
FORESTRY-FISHERY	17.6	7.8	1.7	7.7	6.7	9.8	7.8	41.0
TEXTILES	11.2	10.9	0.3	31.0	3.8	8.7	11.9	22.2
PAPER-WOOD	13.1	16.4	0.7	13.2	5.2	6.9	14.1	30.3
BIO-SUPPLY	7.4	28.3	0.3	2.8	5.7	3.7	7.2	44.7
BIOENERGY	11.7	17.7	1.2	14.9	5.0	7.0	14.4	28.0
BIOCHEMICALS	12.8	12.7	1.9	7.0	20.3	3.5	9.0	32.7

Source: authors' own calculation

4.3 EU28 bioeconomy market prices and world prices

Consistent with other similar studies (e.g., Baldos and Hertel, 2014, OECD FAO 2015) EU28 (Table 11) and world commodity prices (Table 12) witness downward trends in all sectors. As expected, it is the projections shocks which dominate in shaping the path of prices over time. In the EU28 (as in other regions), economy wide (Hicks neutral) productivity growth to meet target rates of real GDP growth implies a reduction in nominal prices. In primary agriculture, there is the additional price depressing impact of rising land productivities, where land is sectorally trapped within a slower growing EU agricultural sector (see result in section 4.2). Consequently, it is these same projections effects in each region which lead to falling world commodity prices. Thus, whilst it is the case that in true Malthusian fashion, increasing population leads to higher agricultural and food prices (not shown), these are more than mitigated by productivity improvements.

The role of the CAP and trade policy is expected to be rather limited in affecting general price levels (Table 11). In the former case, this finding is particularly positive in that CAP budgetary reform is not expected to be price distortive on EU or world markets. In the latter, the price result reflects the general consensus that tariff rates are generally of a low magnitude.

Turning to the isolated impact of the EU biofuel mandate (Table 11), there are notable price rises in bioenergy,

TABLE 11
EU28 market prices in aggregated bio-based activities.

	Index 2013=100			Decomposition of index by shocks (2013-2030)					
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG
AGRICULTURE	100	82.2	66.8	66.8	-1.1	-0.1	0.0	0.3	-2.3
FOOD INDUSTRY	100	84.9	70.9	-26.0	-0.9	0.0	0.0	0.0	-2.2
FORESTRY	100	83.6	70.3	-23.1	-1.4	0.0	0.0	-3.6	-1.7
FISHERY	100	84.2	74.6	-18.4	-2.2	0.0	0.1	-4.0	-0.9
TEXTILES	100	85.3	71.4	-25.2	-1.0	0.0	0.0	0.0	-2.4
WEARING APPAREL	100	84.7	69.8	-26.9	-0.8	0.0	0.0	0.0	-2.5
LEATHER	100	84.8	70.3	-26.2	-0.9	0.0	0.0	0.0	-2.6
WOOD	100	85.4	71.8	-24.7	-1.0	0.0	0.0	-0.4	-2.1
PAPER	100	86.8	74.1	-22.9	-0.9	0.0	0.0	-0.1	-2.1
BIOSUPPLY	100	165.9	169.8	-74.9	4.1	-0.2	0.1	149.1	-8.4
BIOENERGY	100	88.2	76.1	-41.3	0.6	-0.2	0.0	18.4	-1.5
BIOCHEMICALS	100	85.1	74.2	-29.4	-1.8	-0.6	0.1	8.0	-2.2
FEED	100	81.6	64.6	-31.7	-1.3	0.0	0.0	-0.2	-2.1
FERTILISERS	100	94.2	87.8	-15.0	0.2	0.0	0.0	-0.1	2.6
FOSSIL FUEL ENERGY	100	78.3	79.1	-11.9	-8.4	0.0	0.0	-0.2	-0.4
REST OF ECONOMY	100	89.3	79.9	-16.9	-1.1	0.0	0.0	0.0	-2.2
RETAIL PRICE INDEX	100	90.0	80.4	-16.7	-0.9	0.0	0.0	0.0	-2.1

Source: authors' own calculation

biochemicals and (in particular) bioeconomy supply (plantations) sectors. Secondly (and perhaps surprisingly), the isolated impact of bioenergy mandates on increasing agricultural prices (through increased competition for land) is only moderate. Finally, the nominal market prices of forestry are depressed under this policy shock, since the increased use of forestry residues impulses output in this sector, which is not met by proportional increases in demand. Indeed, the slight fall in market prices in the downstream wood products sector arise as a result of cheaper forestry inputs. A cursory examination of Table 12 which shows relatively higher world commodity prices for bioenergy commodities in 2030, reveals that the rise in EU import demands arising from the biofuel mandate has important repercussions in small scale infant industries producing bioeconomy supply (i.e., pellets) and second-generation (thermal and biochemical technologies) biofuels.

Examining the set of GHG shocks on EU market prices (Table 11), there are two sets of opposing forces in play. On the one hand, via a closure swap, carbon taxes rise to ensure that emissions reductions are enforced across sectors, which (ceteris paribus) leads to rising market (i.e., post-tax) prices. This effect is stronger in those sectors which have a higher proportion of GHG emissions. On the other hand, by dampening economic growth in the EU28 both in absolute and relative terms (i.e., vis-à-vis partner countries), output and consequently income in the EU28 is depressed, which also reduces domestic demand, leading to falling prices. With the exception of the EU28 fertiliser sector, the second effect is the stronger.

TABLE 12
Index (2013=100) of world commodity price changes

	2013	2020	2030		2013	2020	2030
WHEAT	100	82.0	67.3	FORESTRY	100	85.7	75.1
GRAIN	100	85.6	70.8	PETROLEUM	100	67.1	70.6
OILSEEDS	100	83.2	71.9	BIODIESEL	100	76.5	61.2
RAW SUGAR	100	85.7	74.9	BIOETHANOL	100	75.9	60.6
HORTICULTURE	100	84.4	66.3	ELECTRICITY	100	88.9	79.7
CROPS	100	91.6	84.8	CHEMICALS	100	80.4	66.5
CATTLE	100	96.3	79.2	GAS DISTRIBUTION	100	91.4	82.9
PIGS-POULTRY	100	74.8	54.5	PELLETS	100	135.6	117.5
RAW MILK	100	91.5	79.7	THERMAL 2ND-GEN	100	104.2	87.8
MEAT	100	80.7	62.7	BIOCHEM 2ND-GEN	100	106.7	89.6
DAIRY	100	82.8	67.6	FERTILISER	100	82.4	69.3
SUGAR	100	81.2	64.6	TEXTILES	100	79.2	61.2
CRUDE VEGETABLE OIL	100	75.5	59.6	WEARING APPAREL	100	76.2	56.5
OILCAKE	100	80.1	52.4	LEATHER	100	74.7	54.6
VEGETABLE OIL	100	78.2	60.8	WOOD	100	81.6	65.8
OTHER FOOD	100	82.5	68.5	PAPER	100	83.7	69.4
FEED	100	75.8	56.4				

Source: authors' own calculation

4.4 EU28 energy market prices

The trends in EU fossil and bio-based energy market prices are presented in Table 13. In the case of the fossil fuel industries (crude oil, gas and coal), the dip in market prices in 2020, compared with 2013 and 2030, is motivated by the assumptions regarding the evolution of world crude oil, gas and coal prices (see Table 5). These assumptions also largely explain the evolution of prices in the fossil fuel refining, energy distribution and output sectors. The market prices for electricity and gas distribution continue to fall in the 2020-2030 period despite rising fossil fuel prices owing to considerable substitution in favour of new capital goods. [18]

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TABLE 13
Index (2013=100) of market price changes in EU energy sectors

	2013	2020	2030
CRUDE OIL	100	69.7	90.6
PETROLEUM	100	69.7	76.5
BIODIESEL	100	78.0	63.7
BIOETHANOL	100	78.6	66.7
GAS	100	93.9	103.7
COAL	100	90.5	117.4
ELECTRICITY	100	92.8	83.0
GAS DISTRIBUTION	100	93.8	85.1
BIOELECTRICITY	100	125.6	106.6
THERMAL 2ND-GEN	100	126.1	107.0
BIOCHEM 2ND-GEN	100	127.6	108.0
RETAIL PRICE INDEX	100	90.0	80.6

TABLE 14
EU28 bio-based employment (1000's head)

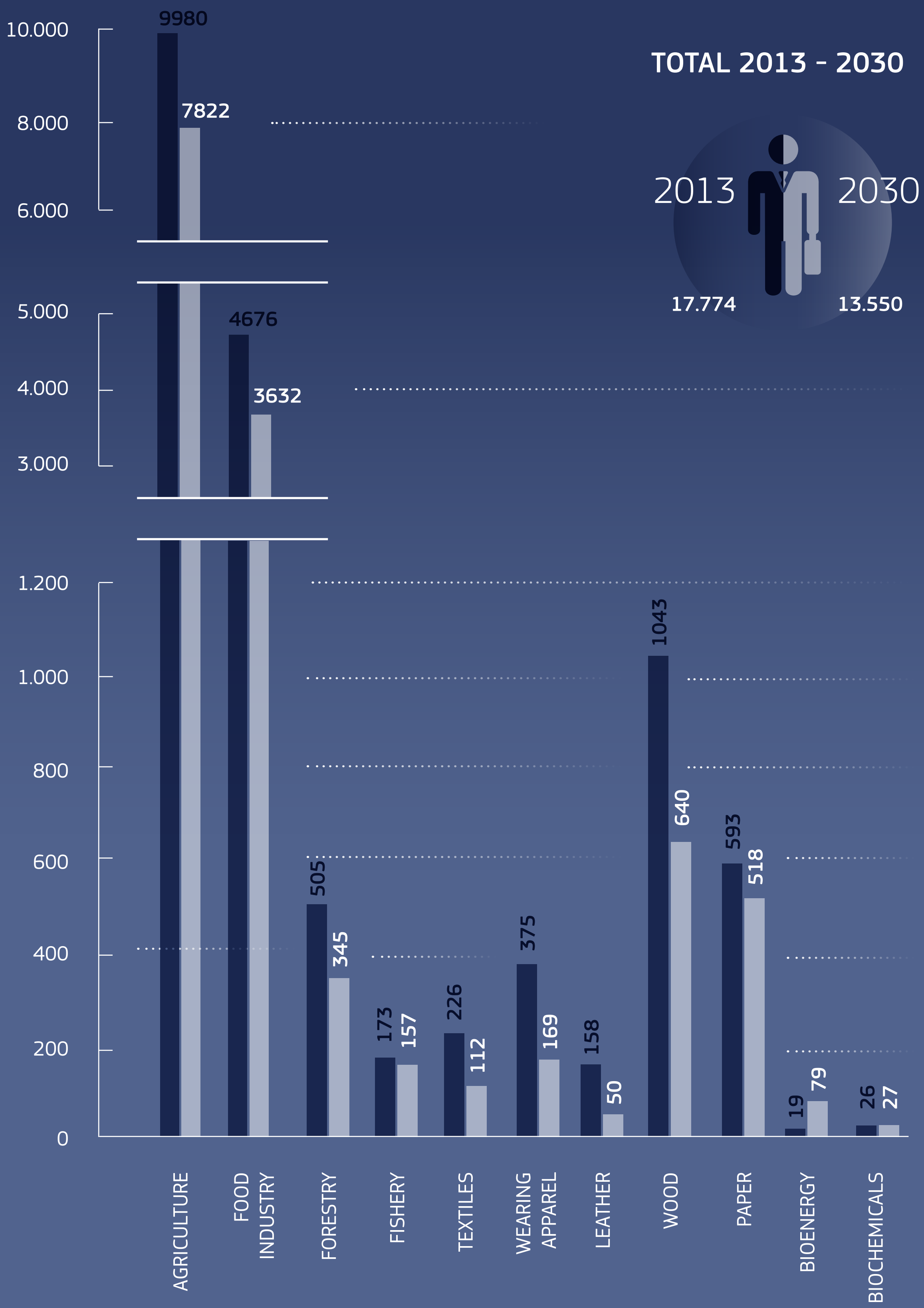
	2013	2020	2030
BIO-BASED EMPLOYMENT	17,774	16,207	13,550
AGRICULTURE	9,980	9,189	7,822
FOOD INDUSTRY	4,676	4,307	3,632
FORESTRY	505	449	345
FISHERY	173	170	157
TEXTILES	226	180	112
WEARING APPAREL	375	289	169
LEATHER	158	107	50
WOOD	1,043	893	640
PAPER	593	569	518
BIOENERGY	19	27	79
BIOCHEMICALS	26	26	27
SHARE OF TOTAL (%)	8.08	7.20	5.73

Source: authors' own calculation

In the first generation bioenergy (biodiesel, bioethanol) sectors, the market price trend is declining over the 2013-2030 period, owing to the assumptions on sector wide productivity improvements, which, even in the period 2013-2020, outweighs the price inflating impact of the mandate. The impact of the mandate (2013-2020) is much more pronounced in the second generation (thermal and biochemical), biofuels and bioelectricity sectors, owing to bottlenecks in the supply of small scale or infant industry bioeconomy feedstock (i.e., plantations, pellets, residues) to these sectors, although with ongoing productivity improvements, market prices in these sectors return to a downward trend in the 2020-2030 period.

[18] In the production nest, capital–energy substitution is assumed to be elastic (=2). The uptake of more efficient capital technology over the ten year period mitigates prices rises arising from different sources of fossil fuels inputs.

TABLE 14
EU28 BIO-BASED EMPLOYMENT (1000'S HEAD)



4.5 EU bioeconomy employment and wages

The employment trends measured in thousands of head for the EU28 bio-based sectors are presented in Table 14. The general trend is that bioeconomy employment is falling in favour of non-bio-based sector employment due to role of the projections shocks (see discussion in section 4.2). In the traditional bio-based sectors employment falls, especially in the EU textiles, wearing apparel, leather and wood sectors, which are considerably more open to import competition. Overall, bioeconomy employment in the EU28 falls from an estimated 17.8 million persons in 2013 to 13.6 million by 2030. This general drop does disguise increasing employment opportunities in the growing bioenergy sectors (from 19,000 to 79,000), but this small sector increase cannot mitigate the general trend that by 2030, bio-based employment will amount to 5.73% of total EU28 employment (vs. 8.08% in 2013). Pg 54

In Table 15 the change in nominal wages by bio-based sectors is presented. The isolated impact of the projections once again dominates. Rising labour endowments depress wages, whilst rises in capital demand also increase labour demand, thereby increasing nominal wages (not shown). Region wide productivity growth to meet real GDP increases depresses nominal wages (not shown), whilst this impact is even more striking in agriculture since the labour movements between agricultural and non-agricultural sectors are assumed sluggish, such that excess agricultural labour supply is willing to accept even lower wages before leaving the sector. In addition, labour-saving land productivity improvements in primary agriculture also depress agricultural labour wages. As a result, the wage differential between agricultural and non-agricultural labour grows considerably over the period, although measured in real wage terms (i.e., comparing with the trend on the EU retail price index in the bottom row), real wages in all sectors, including agriculture, rise over the 2013-2030 period.

Examining the remaining sets of exogenous shocks, the impacts of CAP, trade and biofuels policies are negligible. On the other hand, the EU GHG limits impose wage restraint as EU28 economic growth is reduced by tighter GHG emissions curbs relative to other (non-) EU regions.

[19] In all but two sectors, employment data for 2013 was taken from Eurostat (2015). In the biofuels sector, a 2011 estimate of 19,000 workers is employed (Piotrowski and Carus, 2015), whilst employing the same reference, it is assumed that 5% of the chemical sector workforce is dedicated to biochemical 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.

TABLE 15
Nominal wages in EU bio-based sectors

	Index 2013=100			Decomposition of index by shocks (2013-2030)					
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG
AGRICULTURE	100	89.6	82.1	-13.5	0.0	0.0	0.0	0.2	-4.6
FOOD INDUSTRY	100	100.7	103.1	6.4	-0.2	0.0	0.0	-0.1	-3.1
FORESTRY	100	102.0	106.3	9.6	-0.1	0.0	0.0	-0.1	-3.3
FISHERY	100	98.8	100.1	3.5	-0.1	0.0	0.1	-0.1	-3.3
TEXTILES	100	100	102.3	5.6	-0.2	0.0	0.1	-0.1	-3.1
WEARING APPAREL	100	100.5	103.5	6.9	-0.2	0.0	0.0	-0.1	-3.2
LEATHER	100	99.0	100.9	4.3	-0.2	0.0	0.1	-0.1	-3.3
WOOD	100	100.7	103.5	6.8	-0.2	0.0	0.0	-0.1	-3.1
PAPER	100	100.4	102.4	5.6	-0.2	0.0	0.1	-0.1	-3.0
BIOSUPPLY	100	101.5	104.4	7.6	-0.1	0.0	0.0	0.0	-3.1
BIOENERGY	100	100.7	103.5	6.8	-0.2	0.0	0.1	-0.1	-3.1
BIOCHEMICALS	100	102.3	107.5	10.9	-0.1	0.0	0.0	-0.1	-3.3
FEED	100	100	101.8	5.0	-0.1	0.0	0.1	-0.1	-3.1
FERTILISERS	100	101.1	104.6	7.9	-0.1	0.0	0.1	-0.1	-3.2
FOSSIL FUEL ENERGY	100	101.0	103.9	7.2	-0.2	0.0	0.0	-0.1	-3.1
REST OF ECONOMY	100	100.4	102.3	5.5	-0.2	0.0	0.1	-0.1	-3.0
RETAIL PRICE INDEX	100	90.0	80.4	-16.7	-0.9	0.0	0.0	0.0	-2.1

Source: authors' own calculation

4.6 EU land markets

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In MAGNET, parameterised estimates of land response by each of the GTAP regions are taken from a land use model known as IMAGE (Eickhout et al., 2009). The results of the reference scenario (Table 16) show that land usage by 2030 for most regions remains reasonably close to its 2013 levels. Examining the part-worth values, increasing domestic demand resulting from real growth, endowment and population projections pushes up land usage, although these are mitigated by land productivity improvements (not shown). Overall, with the exception of China and India, which exhibit the highest assumed rates of economic and population (India only) growth, the set of projections shocks depresses land usage (particularly in Japan which has projected falls in population and sluggish relative rates of real GDP growth resulting in further reductions in agricultural competitiveness– see Table 2 in annex). In the EU28, land usage falls by 2.2%. The budgetary reform of the CAP slightly reduces EU land usage (-0.7%) as marginal land leaves production, whilst perhaps surprisingly, the biofuel mandate only generates slight increases in land use in the EU28. The EU biofuel mandate also has minor impacts on land usage in North America, and Mercosur as a result of increases in EU bioenergy imports to meet the internal mandated blending target.

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In contrast to the global land use trends, the changes in real land rental rates are much more pronounced (Table 17). The same projections drivers (pulling in different directions) are once again in play, although the magnitudes also reflect an assumption of available land capacity (i.e., supply elasticity) in each region. With more inelastic

TABLE 16
Region land usage

	Index 2013=100			Decomposition of index by shocks (2013-2030)					
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG
EU28	100	98.3	97.8	-1.5	0.1	-0.7	0.0	0.1	-0.2
NORTH AMERICA	100	97.9	96.0	-1.3	0.7	0.0	-0.5	0.4	-3.3
MERCOSUR	100	100.3	105.3	-15.4	1.0	0.0	0.1	0.4	19.2
RUSSIA	100	99.8	96.0	-2.7	0.4	0.0	0.1	0.3	-2.1
CHINA	100	103.2	104.3	4.1	0.0	0.0	0.0	0.0	0.2
INDIA	100	100.1	100.2	0.1	0.0	0.0	0.0	0.0	0.0
JAPAN	100	97.2	90.3	-9.4	-0.2	0.0	0.0	0.1	-0.1
ROW	100	97.2	99.5	-15.1	-1.7	0.0	0.1	0.1	16.2

Source: authors' own calculation

land supply, Chinese and Indian real land rents are expected to rise significantly in the face of aggressive real economic growth. On the other hand, for the reasons discussed above, Japanese real land rents fall markedly. In the EU, real land rents also fall more than in most other regions due to the CAP budgetary reforms in the period, 2013-2020. More specifically, the rental fall reflects the lost capitalisation from the reduction of Pillar 1 payments which are tied to the land factor..

Table 18 presents the share of land across the world dedicated to first generation (biodiesel and bioethanol) and second generation (biochemical and thermal technologies) biofuels over the period 2013-2030. Given the imposition of the EU mandate, land devoted to biofuel feedstock moves from 1.39% (approximately 26,300 km2) of the EU's land area in 2013, to 3.29% (approximately 60,800 km2) by 2030. Given the infant industry status of second generation biofuels, by 2030, EU land for second generation feedstocks still only amounts to 154 km2 (not shown). As significant suppliers of biodiesel and bioethanol on world markets, similar trends in Mercosur and North America are also witnessed between 2013 and 2030. Pg 60

[20] In the modified GTAP data structure, biofuels do not demand land inputs directly, but rather purchase inputs which require land. For example, first generation biodiesel employs crude vegetable oil ('cvol'), which in turn, demands agricultural (land using) inputs. Thus, the numerator is calculated as the sum of land (in km2) dedicated to each agricultural input 'i' multiplied by the cost share of input 'i' used in cvol, multiplied by the cost share of cvol employed in biodiesel production. Dividing this by the total land area available in region 'r' yields a land share calculation for biodiesel. A similar approach is employed for first generation bioethanol, which demands wheat, other grains and sugar beet/cane directly. In the case of second generation biofuels, land usage is restricted to purchase of the 'plantations' input.

[21] Land usage in km2 is calculated using the data from the IMAGE model which underpins the land module in MAGNET.

TABLE 16
Region land usage

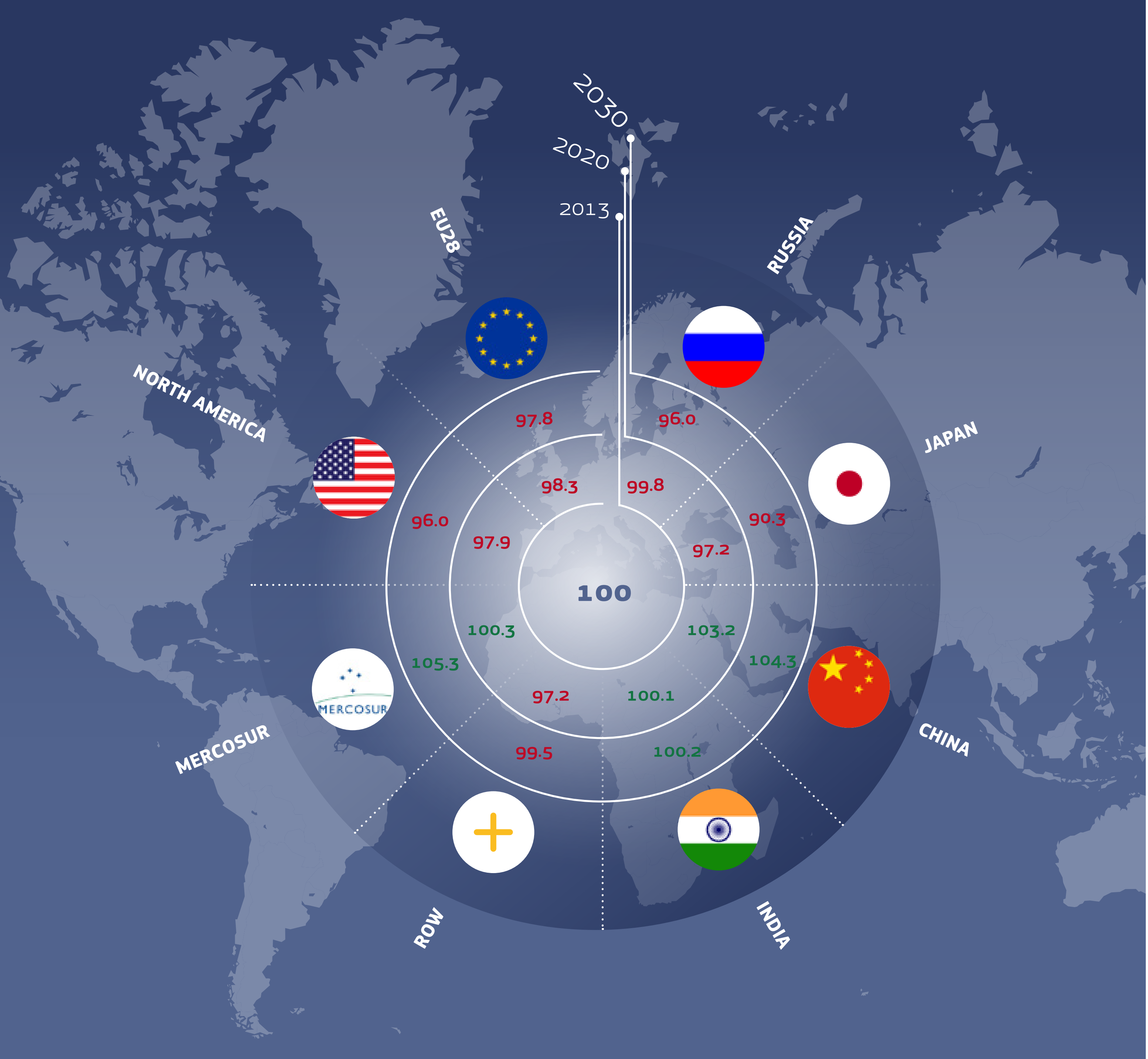

TABLE 17
Region nominal land rent changes

	Index 2013=100			Decomposition of index by shocks (2013-2030)					
	2013	2020	2030	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG
EU28	100	74.4	62.4	-25.8	-0.4	-8.3	0.1	1.0	-4.2
NORTH AMERICA	100	89.0	78.0	-15.8	0.1	0.0	-0.1	0.4	-6.6
MERCOSUR	100	85.9	81.3	-32.0	-1.0	0.0	0.0	0.4	13.8
RUSSIA	100	82.6	74.8	-21.0	-3.5	0.0	0.0	0.0	-0.8
CHINA	100	142.8	162.0	59.3	-0.9	0.1	0.2	0.3	3.0
INDIA	100	172.7	219.2	107.4	2.2	0.1	0.0	0.2	9.4
JAPAN	100	64.3	29.8	-63.9	-4.3	0.0	0.1	1.0	-3.1
ROW	100	87.3	86.0	-33.5	-2.3	0.0	0.2	0.2	21.3

Source: authors' own calculation

TABLE 18
Share (%) of land use devoted to 1st and 2nd generation biofuels

2013	EU28	N. AMERICA	MERCOSUR	RUSSIA	CHINA	INDIA	JAPAN	ROW
BIOETHANOL (1ST-GEN)	0.54	2.87	0.48	0.00	0.14	0.00	0.00	0.01
BIODIESEL (1ST-GEN)	0.85	0.76	0.36	0.00	0.21	0.00	0.00	0.04
BIOCHEM 2ND-GEN	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
THERMAL 2ND-GEN	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TOTAL	1.39	3.63	0.84	0.00	0.34	0.00	0.02	0.05

2030	EU28	N. AMERICA	MERCOSUR	RUSSIA	CHINA	INDIA	JAPAN	ROW
BIOETHANOL (1ST-GEN)	1.25	3.47	1.01	0.00	0.09	0.00	0.00	0.02
BIODIESEL (1ST-GEN)	2.04	2.85	1.69	0.01	1.02	0.00	0.00	0.13
BIOCHEM 2ND-GEN	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
THERMAL 2ND-GEN	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TOTAL	3.29	6.32	2.70	0.01	1.10	0.00	0.03	0.15

Source: authors' own calculation

4.7 Trade competitiveness

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In Table 19 the changes in the trade balances over the 2013-2030 period are presented. Over the 17 year time period, significant imports of textiles, leather, clothing, wood and paper commodities worsen the bioeconomy trade balance considerably. The agricultural trade deficit improves slightly, whilst the EU food trade deficit worsens. In the rest of the world, China, with its strong economic growth and slow internal population increase, solidifies its position as the 'workshop of the world' in the traditional bioeconomy sectors of food, textiles, clothing, wood and paper as well as non bioeconomy trade. At least half of the Russian trade balance improvement is due to its oil exports (not shown), whilst aggressive economic and population growth projections in India result in a considerably fossil fuel energy (not shown) and agrifood import bill.

As a traditional source of agrifood provision on world markets, Mercosur's agrifood trade balance does not change considerably, despite increases in agricultural and food production, coupled with increased land uptake. This suggests that given Mercosur's high predicted increases in population and growth, much of the demand for agrifood production increases, is consumed internally.

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In Table 20, we examine in more detail the evolution of extra and intra-EU trade. With slower rates of EU macro growth, and greater trade openness in textile, clothing, paper and wood industries, extra-EU imports (columns 2-4, Table 20) rise considerably over the 2013-2030 period. A very signifiant increase in bioeconomy supply (pellets – from a very small base) and bioenergy extra-EU imports is observed, to enable the EU to meet its biofuel mandate requirement. EU output in forestry and fishing (see Table 8) appear sufficient to satisfy domestic requirements, such that extra-EU imports fall.

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.Pg 49
.Pg 63

Extra-EU exports (columns 5-7, Table 20) generally rise (fall) in those sectors where domestic output increases (decreases) (section 4.2, Table 8). With the exception of forestry and fishing, the trend for intra-EU trade (columns 8-10, Table 20) is one of falling, or slower rates of growth (vs. extra-EU imports), suggesting a greater reliance on extra-EU (bioeconomy) sources of trade. It should be noted, however, that dramatic rises in intra-EU bioeconomy supply (i.e., pellets) and bioenergy trade resulting from the mandate, leads to redistribution in member state specialisation in bioenergy products.

To capture the concept of trade competitiveness, the Balassa index of revealed comparative advantage (RCA) is employed, based on the following formula:

$$RCA_{i,j} = \frac{X_{i,j} / X_i}{X_{a,j} / X_a}$$

[22] Biochemicals are assumed non-tradable. A 2013 exchange rate is employed (1\$=0.7533€).

[23] Much of this is due to Germany's diminished role as a principal bioenergy provider amongst EU member states. The reason for this is because the mandate obliges other EU member states to catch up with the German level of blending. This was discussed in section 4.2.

where xij are exports of product 'j' from country 'i'; Xi is total exports from country 'i'; xaj denotes total exports of 'j' from area 'a' (e.g., the world); and Xa are total exports from reference area 'a'. Thus, a country is said to have a comparative advantage in exports of a product 'j', if its market share in the country's exports is higher than the average market share of product 'j' in the exports of the reference area. Thus, a country is said to exhibit a comparative advantage in products for which this indicator is higher than 1. In **Table 21**, computed values of RCA for 2013 and 2030 are presented for a number of regions. .Pg 64

Examining the situation in 2013, the EU28 shows trade competitiveness in the bio-based sectors of food, fishing, wood and paper products. Examining bioeconomy trade competitiveness in other regions, Mercosur exhibits competitive RCA indices for (in particular) bioenergy, agriculture and food, as well as leather and paper products; whilst the most competitive bio-based North American sectors are (in order) bioenergy, agriculture, paper products, bioeconomy supply and fishing. In China and India, bioeconomy trade competitiveness is concentrated in the textiles, wearing apparel, leather products and (China only) wood products industries. Perhaps most strikingly, Japan is found to have a very uncompetitive bioeconomy sector.

Comparing 2013 with 2030 (**Table 21**, bottom half), only in food and bioenergy sectors, does the EU's RCA indicator (slightly) improve. This is contrast to the marked RCA index decline in EU textiles, wearing apparel, leather and wood products sectors, and to a lesser extent in paper products. As mentioned previously, China is taking advantage of the EU's relative weakness in these bio-based sectors, although given internal demand pressures arising from rapid economic growth, its RCA indicators only improve for bio-based textiles, wood and paper products. Similarly, in India, aggressive internal demand also explains India's declining RCA values in many of its sectors (a notable exception being bioenergy). Finally, in agricultural trade, the EU's RCA index does not decline too significantly despite the CAP budgetary reforms (given the decoupled nature of much of EU agricultural support), whilst EU food trade competitiveness remains steady. In the non EU regions, Mercosur strengthens its competitive position as the 'breadbasket of the world' with an improving RCA index in both agricultural and food sectors. North America and the Rest of the World also improve their competitive RCA index ratings for agriculture, whilst in China, at the same time that agricultural competitiveness declines, the food RCA index rises. This suggests that whilst relatively more agricultural goods are being consumed domestically, greater volumes of higher value added food products are steadily being exported by Chinese manufacturers. .Pg 64

[24] Note that although the EU's RCA for food rises slightly between 2013 and 2030, the EU's food trade balance (exports minus imports) declines over the same period. It is therefore important to note that the RCA measure only provides a metric for examining relative 'export' competitiveness but has nothing to say about trade dependence.

TABLE 19
Changes in trade balances between 2013-2030 (€ million, 2013 prices)

	EU28	N. AMERICA	MERCOSUR	RUSSIA	CHINA	INDIA	JAPAN	ROW
TOTAL	-176,626	-360,687	9,034	63,302	314,207	-23,585	-127,695	302,056
BIOECONOMY	-140,882	-85,437	1,986	8,957	271,552	-24,545	6,576	-102,594
AGRICULTURE	6,051	-5,256	-1,295	2,675	-9,888	-21,661	4,559	23,097
FOOD INDUSTRY	-24,208	-12,348	4,223	4,700	41,339	-3,782	3,200	-23,158
FORESTRY	1,211	-64	34	852	-756	-2,992	395	809
FISHERY	1,534	182	30	-5	832	-408	592	-3,378
TEXTILES	-21,508	-10,674	-1,050	-71	51,340	-2,447	-634	-22,883
WEARING APPAREL	-38,273	-24,523	-1,230	-780	90,176	4,478	-959	-45,581
LEATHER	-16,166	-3,905	-2,616	-395	32,297	-264	130	-17,050
WOOD	-20,531	-20,640	-669	1,229	40,701	546	987	-14,461
PAPER	-17,993	-10,821	897	517	24,853	1,863	-1,730	-2,772
BIOSUPPLY	-3,367	861	367	232	519	1	17	1,281
BIOENERGY	-7,632	1,750	3,295	4	139	122	19	1,501
REST OF ECONOMY	-35,744	-275,250	7,048	54,345	42,655	960	-134,271	404,649

Source: authors' own calculation

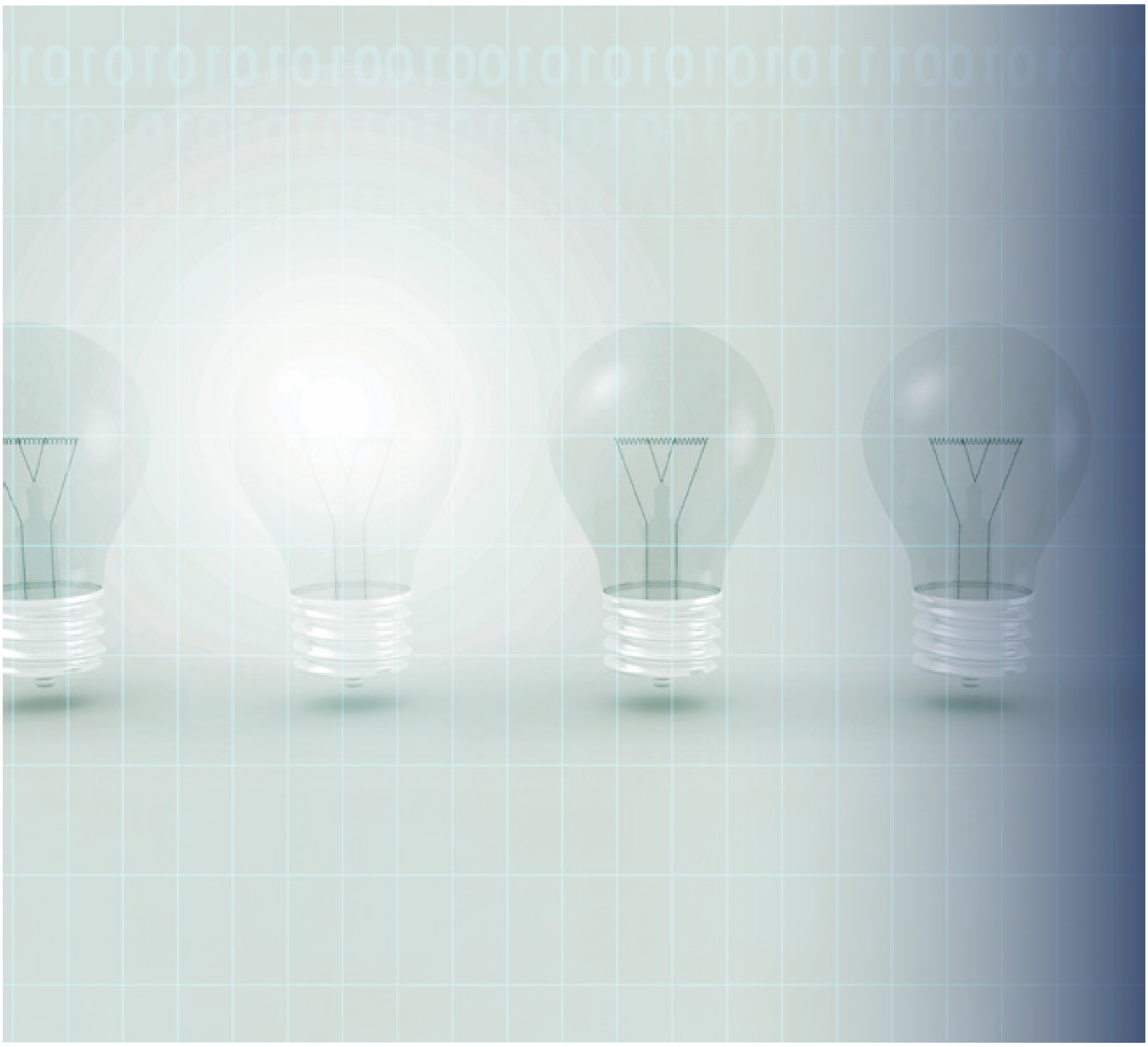
TABLE 20
Index (2013=100) of EU28 bioeconomy trade volume changes

	EXTRA-EU28 IMPORTS			EXTRA-EU28 EXPORTS			INTRA-EU28 TRADE		
	2013	2020	2030	2013	2020	2030	2013	2020	2030
INTRA-EU28 TRADE	100	104.6	120.1	100	108.0	111.9	100	98.0	96.2
FOOD INDUSTRY	100	131.7	203.6	100	96.7	118.7	100	102.9	108.2
FORESTRY	100	91.2	84.8	100	138.9	197.3	100	102.7	106.4
FISHERY	100	90.0	90.7	100	142.1	317.2	100	111.2	117.7
TEXTILES	100	145.3	208.4	100	71.7	50.6	100	79.6	61.8
WEARING APPAREL	100	175.5	283.1	100	53.3	30.6	100	60.3	35.4
LEATHER	100	167.7	253.5	100	47.3	24.4	100	51.9	27.6
WOOD	100	157.0	230.7	100	87.7	76.8	100	90.2	81.4
PAPER	100	155.3	237.6	100	96.7	96.0	100	104.6	110.1
BIOSUPPLY	100	2794.1	5202.5	100	428.5	359.4	100	729.1	1003.7
BIOENERGY	100	222.6	664.9	100	111.5	442.5	100	184.5	509.9

Source: authors' own calculation

TABLE 21
Balassa index of revealed comparative advantage (RCA) in the bioeconomy

		AGRICULTURE	FOOD INDUSTRY	FORESTRY	FISHING	TEXTILES	WEARING APPAREL	LEATHER	WOOD	PAPER	BIOSUPPLY	BIOENERGY
EU28	2030	0.77	1.31	0,71	1,25	0,34	0,10	0,11	0,80	1,44	1,83	0,82
	2013	0,80	1,29	0,71	1,07	0,64	0,41	0,51	1,10	1,49	1,93	0,71
NORTH AMERICA	2030	2.10	0.62	0.83	1.04	0.15	0.02	0.02	0.59	1.46	1.27	3.92
	2013	1,98	0.72	0.93	1.03	0.30	0.07	0.08	0.83	1.58	1.34	3.08
MERCOSUR	2030	5.39	4.34	0.41	0.28	0.20	0.03	0.57	0.80	1.27	1.87	12.39
	2013	5.05	3.91	0.38	0.22	0.29	0.07	1.32	0.95	1.06	0.34	15.13
RUSSIA	2030	0.80	0.45	8.93	0.47	0.05	0.01	0.04	0.93	0.53	1.31	0.01
	2013	0.64	0.43	8.38	0.60	0.05	0.02	0.06	0.77	0.50	1.84	0.00
CHINA	2030	0.19	0.95	0.07	0.66	3.81	5.33	5.64	3.40	1.32	0.39	0.05
	2013	0.36	0.58	0.09	0.56	3.52	5.52	5.90	2.73	0.81	0.14	0.02
INDIA	2030	0.07	0.47	0.10	0.06	1.86	1.79	0.93	0.26	0.50	0.00	0.24
	2013	0.51	0.80	0.52	0.22	2.89	2.38	1.61	0,26	0.30	0.00	0.05
JAPAN	2030	0.05	0.10	0.02	0.85	0.25	0.01	0.01	0.05	0.26	0.05	0.04
	2013	0.03	0.10	0.02	0.46	0.42	0.02	0.03	0.08	0.33	0.05	0.01
REST	2030	1.13	0.84	1.24	1.13	0.64	0.26	0.15	0.40	0.53	0.64	0.28
	2013	1.00	0.90	1.22	1.27	0.89	0.66	0.39	0.58	0.52	0.36	0.19



4.8 Greenhouse gases

In Table 22, the changes in EU28 GHG emissions by sector aggregates over the 2013-2030 period are shown. It should be noted with a lack of forestry land sequestration data in the current model, one cannot quantify potentially harmful environmental impacts resulting from the uptake of additional land to meet bioenergy mandates. Given the assumed reference scenario path of EU28 GHG emissions (reduction of 12.2 percentage points over the 2013-2030 period), most sectors undergo GHG emissions reductions. By dividing the quantity of emissions for each of the aggregate sectors by the output value of the sector, one derives a measure of emissions intensity per activity. As a result, those sectors which emit a larger quantity of tonnes of CO2 equivalent (CO2e) per thousand euros of output value (tCO2e/000€ - see Table 22), such as fertiliser and fossil fuel sectors, reduce their GHG emissions far below the EU28 economy average. The mitigation of GHG emissions arising from these activities is performed by technological substitution in favour of cleaner or more extensive (in the case of fertiliser) production technologies.

As a sector with a relatively higher tCO2e/000€ ratio, agricultural output rises recorded in Table 8 are muted compared with other bio-based sectors, in part due to the restraining impact of GHG emissions reductions. A large proportion of the emissions reductions are realised by output contractions in the livestock sectors (not shown), where a large proportion of GHG emissions are activity (output) driven (see also section 4.2).

Compared with the reference scenario in the analysis undertaken with the CAPRI model (see ECAMPA project, Perez-Dominguez et al., forthcoming) which does not impose any GHG constraint on the agricultural sector, the reference scenario in this study implies a 4.3% reduction of emissions in the agricultural sector. This, together with other methodological differences, explains the fact that results are not fully comparable.

In contrast, the EU28 residual sector, 'rest', increases emissions since it emits considerably less per thousand dollars of output value, whilst it provides a solid source of economic growth in response to the EU macroeconomic assumptions employed in the simulations. In the textiles, wearing apparel and leather products sectors, emissions reductions are largely motivated by falling output due to increased import competition (see section 4.2).

The main objective of this study, a multi-perspective approach, should be recalled. Therefore, some of the climate policies (e.g., differentiation between ETS and non ETS or auctioning in the power sector) and renewable energies are not represented in all details. This might influence the results for some of the affected sectors.

[25] Whilst it is possible to include forestry land within MAGNET (and an associated Constant Elasticity of transformation function), it is also necessary to have some grasp of the level of stored carbon in forestry by type and vintage of the tree. In addition, some assumption would be required regarding forestry sequestration changes under afforestation/deforestation which again, may vary by the type of tree, the forestry management regime and the vintage of the forest.

TABLE 22
EU28 greenhouse gas emissions

tCO_2/€1000	2013	GHGmt/CO_2e
1.11	Agriculture	360.9
0.05	Food Industry	51.4
0.11	Forestry	3.9
0.32	Fishery	7.0
0.04	Textiles	5.5
0.02	Wearing Apparel	2.2
0.02	Leather	1.2
0.02	Wood	3.5
0.06	Paper	32.4
3.45	Fertilisers	14.5
1.25	Fossil Fuel Energy	1,425.4
0.08	Rest of Economy	1,808.9
	Final Demands	624.5
	EU28 Total	4,341.3

INDEX 2013 = 100

2020	2030	
97.8	95.7	AGRICULTURE
98.8	96.7	FOOD INDUSTRY
93.3	83.1	FORESTRY
97.4	88.0	FISHING
85.5	73.1	TEXTILES
81.4	66.5	WEARING APPAREL
69.5	48.9	LEATHER
92.1	81.3	WOOD
101.8	103.3	PAPER
75.8	59.7	FERTILISERS
65.0	56.8	FOSSIL FUEL ENERGY
106.9	108.4	REST OF ECONOMY
100.4	96.1	FINAL DEMANDS
91.1	88.1	EU28 TOTAL

Source: authors' own calculation

4.9 Evaluating the impact of fossil fuel price variations

A number of additional scenarios are rerun focusing on the prices of fossil fuels. More specifically, an ad hoc approach is employed where in the periods 2013-2020 and 2020-2030, the assumed annual rates of change in world fossil prices diverge from the reference scenario. Thus, in the second period, the assumed per annum average price falls are now between 25% less to 25% more than the reference scenario. Similarly, in the second period, the per annum average price rises are now between 25% less to 25% more than the reference scenario. The exact shocks employed in periods two and three are detailed in Table 23, resulting in four additional scenario

TABLE 23
World fossil fuel price shocks

		REFERENCE SCENARIO 2030	SCENARIO 1 25% LOWER	SCENARIO 2 10% LOWER	SCENARIO 3 10% HIGHER	SCENARIO 4 25% HIGHER
2013-2020	COAL	-11.66	-14.75	-12.89	-10.45	-8.64
	CRUDE OIL	-30.92	-39.82	-34.42	-27.50	-22.51
	GAS	-7.40	-9.32	-8.17	-6.64	-5.51
2020-2030	COAL	20.48	15.04	18.28	22.73	26.16
	CRUDE OIL	22.81	16.71	20.34	25.33	29.20
	GAS	9.30	6.91	8.34	10.27	11.74

Source: authors' own calculation

TABLE 24
Per capita real incomes (2013=100) under varying world fossil fuel prices

	2013	REFERENCE SCENARIO 2030	10% LOWER 2030	25% LOWER 2030	10% HIGHER 2030	25% HIGHER 2030
EU28	100	129.0	129.3	129.9	128.6	128.2
USA	100	136.8	137.6	138.4	136.4	135.9
CANADA	100	122.8	122.6	122.8	122.7	122.5
MERCOSUR	100	150.7	150.3	150.3	150.8	150.8
RUSSIA	100	170.3	168.8	166.6	171.3	172.5
CHINA	100	252.0	252.0	252.8	251.6	251.3
INDIA	100	228.3	228.7	230.0	227.4	226.6
JAPAN	100	127.9	128.3	129.1	127.6	127.1
AUSTRALIA & NEW ZEALAND	100	102.4	102.4	102.5	102.4	102.4
MENA	100	153.4	151.7	149.1	154.8	156.7
SSA	100	159.6	158.8	157.5	160.3	161.1
ROW	100	158.8	158.7	159.4	158.4	157.9

Source: authors' own calculation

TABLE 24

Per capita real incomes (2013=100) under varying world fossil fuel prices

runs.
In general the macro impacts are muted. For example, the impact on per capita real incomes is presented in Table 24. As expected, compared with the reference scenario, net importers of raw energy (e.g., EU, USA, China, India and Japan) experience small per capita real income gains which increase as world fossil fuel prices fall. The opposite is the case for net exporters of raw energy commodities (i.e., Mercosur, MENA and SSA). In the EU, per capita real income is between 0.9 index points higher (25% lower prices) and 0.8 index points lower (25% higher prices). .Pg 68

Examining the retail price index (i.e., inflation) across regions (Table 25), the effect of changing fossil fuel prices is rather more ambiguous. On the one hand, inelastic demands ensure (ceteris paribus) that, for example, falling fossil fuel prices decrease energy bills to industry and consumers, which depresses the retail price index. On the other hand, a general equilibrium effect is also observed. Lower fossil fuel prices generate relatively more buoyant supply conditions, which allows economies to grow more, although with factor endowment shocks unchanged, such growth increases real exchange rates (i.e., factor prices), which generates an inflationary effect. These opposing forces generate an unclear pattern of change in retail prices by regions.

Examining the impacts on EU real GDP (Table 26, bottom row), there is a clear correlation between falling (rising) relative fossil fuel prices and rising (falling) relative real macro growth in the EU, although the EU economy output effect is smaller than the EU economy-wide retail price effect shown in Table 25, which in part reflects the inelastic nature of raw energy demands. A similar inverse correlation between relative output and price changes is also observed in the fossil fuel and energy sector (Table 26). For example, the 25% per annum average price reductions (rises) in fossil fuels lead to EU output rises (falls) in the fossil fuel and energy sector of 2.1 (-1.8)

TABLE 25
Retail price indices (2013=100) under varying world fossil fuel prices

	2013	REFERENCE SCENARIO 2030	10% LOWER 2030	25% LOWER 2030	10% HIGHER 2030	25% HIGHER 2030
EU28	100	80.6	80.4	81.2	80.4	80.9
USA	100	82.9	83.9	83.1	82.7	82.8
CANADA	100	77.8	77.5	77.5	77.8	78.4
MERCOSUR	100	76.9	75.8	75.8	77.2	78.4
RUSSIA	100	76.3	74.6	73.2	77.2	79.3
CHINA	100	72.9	72.7	73.3	72.7	73.1
INDIA	100	78.5	78.4	79.4	78.0	78.3
JAPAN	100	86.2	86.9	88.2	86.7	87.1
AUSTRALIA & NEW ZEALAND	100	79.4	78.9	79.9	79.4	80.0
MENA	100	72.3	70.5	68.8	73.5	75.8
SSA	100	82.6	80.6	78.7	84.0	86.7
ROW	100	76.8	76.3	76.9	76.6	77.1

Source: authors' own calculation

index points. Examining remaining sectors, relative fossil fuel price falls compared with the reference scenario appear to benefit non bio-based activities more. It is implied that non bio-based activities (e.g., heavy industry and construction) have a higher energy intensity compared with bio-based sectors, such that under conditions of cheaper energy prices, this diverts primary resources away from bio-based sectors.

In the bioenergy sector, Table 26 shows a more marked output effect (from a smaller base), which reflects the more elastic responsiveness in petroleum (blending) sector output to relative changes in fossil fuel prices. More specifically, as the only source of demand for biofuels, output rises in the petroleum (blending) sector generate (ceteris paribus) increased derived demands for bioenergy (so-called 'expansion effect'). On the other hand, when increased petroleum demand is generated by lower fossil fuel (crude oil) prices, then blending technologies will favour a greater usage of fossil based energy inputs (substitution effect). As a result, the 'expansion' and 'substitution' effect, particularly in the period 2020-2030 are very much at odds with one another. The underlying finding is that the price effect appears to be stronger, given the technology assumption of an elastic substitutability between bio-based and fossil fuel inputs in the blending sector. [26] Thus, referring to Table 26, with a 25% rise (fall) in relative fossil fuel prices, bioenergy sector output grows (contracts) by approximately

TABLE 26

EU sector output and real GDP growth (2013=100) under varying world fossil fuel prices

	2013	REFERENCE SCENARIO 2030	10% LOWER 2030	25% LOWER 2030	10% HIGHER 2030	25% HIGHER 2030
AGRICULTURE	100	101.8	100.9	100.5	101.3	102.1
FOOD INDUSTRY	100	112.2	111.6	111.2	112.1	112.5
FORESTRY	100	109.0	108.9	108.6	109.1	109.1
FISHERY	100	119.5	119.3	119.3	119.4	119.5
TEXTILES	100	80.8	80.8	80.7	80.9	81.1
WEARING APPAREL	100	76.5	76.7	76.8	76.7	76.7
LEATHER	100	59.8	59.9	60.1	59.8	59.9
WOOD	100	95.2	95.1	94.4	95.7	96.1
PAPER	100	118.8	118.8	118.6	118.8	118.9
BIOSUPPLY	100	239.2	236.8	226.8	242.3	248.9
BIOENERGY	100	367.6	359.1	337.9	385.6	404.4
BIOCHEMICALS	100	131.1	134.0	136.0	130.9	130.0
FEED	100	105.5	104.6	104.8	104.7	105.6
FERTILISERS	100	68.4	66.2	64.9	68.2	68.7
FOSSIL FUEL ENERGY	100	112.3	112.8	114.4	110.4	108.5
REST OF ECONOMY	100	131.9	131.9	132.2	131.7	131.8
REAL GDP	100	131.7	131.8	131.9	131.6	131.5

Source: authors' own calculation

[26] In the reference scenario, the level of subsidy support to the bioenergy industry is maintained fixed in real terms, although the mandate is relaxed and left to adjust endogenously.

37 (-30) index points by 2030. Moreover, we see that the biochemical industry contracts when relatively greater bioeconomy is channelled into bioenergy production, and vice-versa. Given the trends for EU bioenergy output, bioeconomy supply dedicated to biofuel production follows a similar pattern. Moreover, by 2030 the biofuel land share in the EU varies between 2.57% (25% fall in fossil fuel prices) and 3.67% (25% rise in fossil fuel prices) (not shown), compared with 3.29% in the reference scenario.

Finally, the changes in bio-based employment in the EU (Table 27) show a similar trend to the output changes in Table 26. Thus, with rising fossil fuel prices, the size of the bio-based economy grows, accompanied by slight rises in bio-based employment. As a share of total EU employment, the bioeconomy accounts for 5.81% (increase of 0.08% on the reference scenario) with a rise in relative fossil fuel prices of 25%, compared with a corresponding statistic of 5.65% (fall of 0.08% on the reference scenario) with a relative fall of 25% in fossil fuel prices.

TABLE 27

EU sector employment (1000 head) under varying world fossil fuel prices

	2013	REFERENCE SCENARIO 2030	10% LOWER 2030	25% LOWER 2030	10% HIGHER 2030	25% HIGHER 2030
BIO-BASED EMPLOYMENT	17,774	13,550	13,424	13,347	13,636	13,738
AGRICULTURE	9,980	7,822	7,735	7,693	7,898	7,963
FOOD INDUSTRY	4,676	3,632	3,613	3,594	3,633	3,649
FORESTRY	505	345	345	343	345	346
FISHERY	173	157	156	156	156	156
TEXTILES	226	112	112	112	112	113
WEARING APPAREL	375	169	169	170	169	170
LEATHER	158	50	50	50	50	50
WOOD	1,043	640	638	630	644	648
PAPER	593	518	518	516	518	519
BIOENERGY	19	79	60	55	85	102
BIOCHEMICALS	26	27	28	28	25	23
SHARE OF TOTAL (%)	8.08	5.73	5.68	5.65	5.77	5.81

Source: authors' own calculation

5 EUROPEAN BIOECONOMY RESILIENCE UNDER DIFFERENT POLICY FUTURES

A further dimension to this study is to evaluate the resilience of the EU's bioeconomy under different visions which represent how the EU perceives its own role within a future world. Two distinct paradigms taking (deliberately) polar opposite paths are identified, which are characterised by the degree of priority placed on each of the four policy pillars (i.e., CAP, Trade, Biofuels, GHGs). Classified as inward- and outward-looking policy worlds (henceforth known as 'IL' and 'OL'), the underlying ethos of both narratives is based on the degree to which the EU attempts to marry tangible goals such as economic growth and employment generation, with philanthropic concepts of poverty reduction (e.g., improve the incomes of the poor through 'fairer' trade), environmental protection, biodiversity and green growth (i.e., GHG emissions limits, CAP), as well as reduced fossil fuel dependence (e.g., biofuel policy).

In the following sections, the results show comparisons of both policy narratives with the reference scenario (henceforth known as 'RS') for the decade 2020-2030. The discussion focuses on the prospects for the EU bioeconomy under the banners of 'growth, jobs and competitiveness', 'sustainable resource usage' and 'food security'. Once again, when comparing each of the IL or OL with the RS, the comparative 'part-worth' importance of the four policy indicators is evaluated in order to better understand the role that policy has to play (if any) in shaping bio-based market trends.

5.1 EU growth, jobs and competitiveness (2020-2030)

5.2 Sustainable resource usage (2020-2030)

5.3 Food security (2020-2030)

5.1 EU growth, jobs and competitiveness (2020-2030)

In this section, the discussion examines the role of the EU bioeconomy as a pillar of economic progress. In particular, an underlying theme is to formulate a better understanding of the bioeconomy's resilience to different (and sometimes conflicting) EU policy objectives in the medium term. Within this arena, measures of EU bioeconomy performance are gauged in terms of production (absolute and relative changes), job creation and trade competitiveness.

5.1.1 Economic growth, real incomes and general prices

As a starting point for analysing and comparing each of the different narratives, Table 28 presents the impact on a select group of macro indicators across the three policy narratives. Comparing the IL and RS, there is a slight macro improvement for the EU28, both in terms of real growth (0.2%) and per capita utility, or income, (0.4%). Examining the decomposition of the policy shocks, the biggest contributor to both indicators is the elimination of the biofuel mandate policy. Looking at the isolated role of the trade shocks in Table 28 under the conditions of this experiment, the EU's decision to strengthen its neighbourhood policy and promote TTIP generates only a small positive benefit to EU28 real growth (0.01%). This is because these trade deals only contemplate eliminations in what are already relatively low levels of average applied tariff rates (i.e., there are no reductions modelled in 'behind the border' non-tariff measures). Similarly, elimination of all non green Pillar 1 payments in a 'small' sector such as agriculture, as expected, has practically no affect on EU members' economic growth.

A different story emerges when comparing the OL and RS. Macro growth is systematically lower in all EU member states (not shown), whilst for the EU28, this translates into a fall of 1.2% over the 2020-2030 decade, accompanied by a concomitant fall in real per capita incomes of 1.6%. The reasons for this become clear when examining the policy shocks. Whilst the stylised multilateral trade reform is expected to generate (moderate) trade led gains, over the decade, the EU pays an economic price for unilaterally implementing more ambitious GHG limits (1% of its GDP) and higher biofuel mandates (0.6% of its GDP). At the same time, other regions witness small real growth gains (not shown) given the eroding competitiveness of the EU's production activities (bio-based and non bio-based).

TABLE 28

Macro indicators (%) from the IL and OL scenarios compared with the RS (2020-2030)

			Decomposition of index by shocks (2020-2030)						Difference
IL VS RS	RS	IL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	IL Vs RS
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
RETAIL PRICE INDEX	-10.4	-9.4	1.0	-0.6	0.0	0.1	0.1	0.4	1.0
OL VS RS	RS	OL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	OL Vs RS
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
RETAIL PRICE INDEX	-10.4	-10.9	-0.8	1.6	0.0	-0.5	-0.9	0.1	-0.5

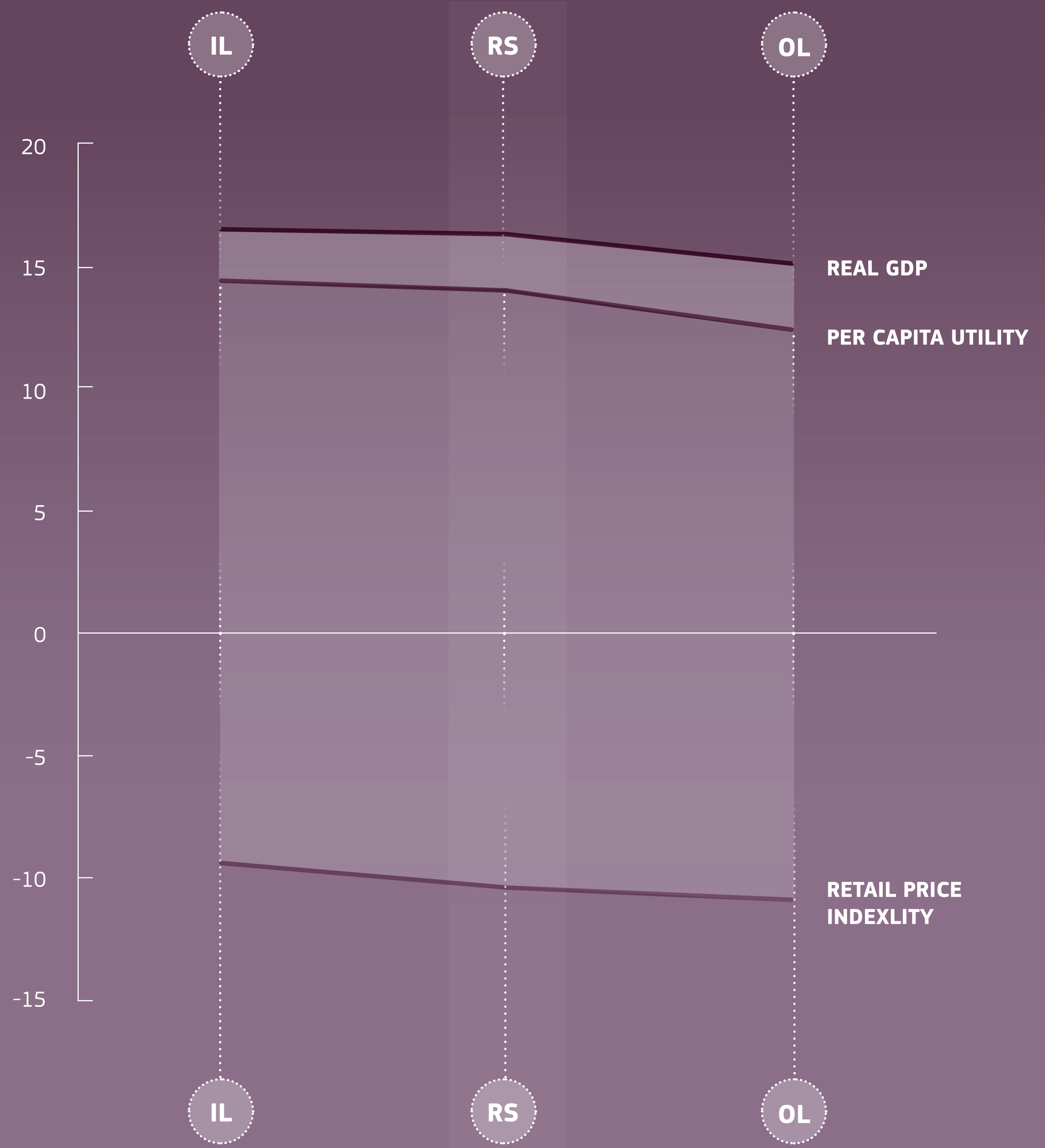
Source: authors' own calculation

[27] The results show that by 2030, the 'average' EU28 carbon tax per tonne of CO2 equivalent (CO2e) of GHG emissions is €15/tonne CO2e in the reference scenario, €27/tonne CO2e in the IL scenarios and €95/tonne CO2e in the OL scenario.

[28] In the reference scenario, it was shown in section 4.1 that the biofuel mandate restrains economic growth due to the negative impact on the petroleum sector.

[29] 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%).

TABLE 28
Macro indicators (%) from the IL and OL scenarios compared with the RS (2020-2030)



The economic cost associated with the GHG emission reduction reveals to be consistent with the cost foreseen by the EC impact assessment on energy and climate policy (EC, 2014). However, the EC (2014) foresees a GDP reduction of about 0.45% in 2030 compared to the baseline, EC (2014).
This is partly explained as the reference EC (2014) has lower emissions in their reference, consistent with EU energy, transport, and greenhouse gas emissions trends to 2050 of the European Commission (2013). The 2030 Framework scenario analyses a GHG production which is about 8% more ambitious than the corresponding reference. This bioeconomy report analysis however has higher GHG emissions in the reference, and here the GHG scenario foresees for an additional 13% GHG reduction beyond the corresponding reference. Further, differences can be explained due to the absence of renewable technologies in the power sector, and the general modelling set up.
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In terms of the general level of prices (**Table 28**), a comparison between the IL and RS scenarios shows a rise of approximately 1%. The fact that the biofuel mandate is abolished provides a (small) general impetus to the EU macro economy, which has the result of increasing primary factor prices across the whole economy. Consequently, relative to the reference scenario, all policy drivers generate higher prices, whilst world price shocks (unchanged from the reference scenario) are relatively cheaper. Comparing the OL and RS, the multilateral trade deal reduces general prices as a result of cheaper imports to third country markets, whilst the brake that the biofuel mandate imposes on EU economic activity results in lower general prices (from factor price falls). The additional EU unilateral GHG emissions reductions slow EU economic growth and depress general prices, although this is more than mitigated by rising carbon taxes on EU activities. With generally lower prices in the EU28 comparing OL with RS, world price shocks (unchanged from the reference scenario) are relatively more expensive.

5.1.2 Bioeconomy output

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The impact of each policy narrative on EU bioeconomy output volumes is presented in **Tables 29 and 30**.
.Pg 80
Comparing the IL with the RS (**Table 29**), an underlying 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 bioeconomy 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) and, by extension, reduced feed and fertiliser usage. Interestingly, biochemicals benefits (19%) as a (now) more attractive alternative source of bioeconomy usage, whilst the large aggregate sectors of fossil fuels and energy and 'rest' also expand output owing to primary resource reallocation effects.

Elsewhere, the part-worth effect of reform of the CAP toward greater market orientation does not (as expected) purge significantly the output of EU agriculture and food. In part, the EU's more measured approach to trade policy appears to pay small dividends for its textiles, leather and wearing apparel sectors (which have contracted notably in the 2013-2030 period in the RS), whilst for EU agriculture and food sectors, the further opening of domestic markets has only a small negative output effect.

.Pg 81
Comparing output change in the OL and RS (**Table 30**), one sees a clear conflict between biofuel policies designed to promote greater non-fossil fuel usage, and overall macroeconomic growth in the EU. The implications of increasing the biofuel mandate has far reaching second-round ripple effects on output across many EU bio-based and supporting industries, but it is also to the detriment of the non-bio-based sectors of the EU economy. For example, the isolated impact of increasing the blending mandate creates significant rises in EU bioeconomy supply (68%) and bioenergy (45%), as well as increases 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, whilst feed and fertiliser output also rises in tandem with greater agricultural demand. Notwithstanding in the large aggregate sectors (fossil fuel energy and 'rest'), this policy generates output falls

TABLE 29
Output volume changes (%) between the IL and RS scenarios (2020-2030)

IL VS RS	RS	IL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
AGRICULTURE	1.7	-2.3	-0.8	-0.9	-1.0	-0.1	-1.2	0.0	-4.0
FOOD INDUSTRY	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
FISHERY	10.1	7.9	-0.5	-0.2	0.0	-0.1	-1.4	0.0	-2.2
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	-20.1	-19.6	0.4	-0.2	0.1	0.2	-0.1	0.1	0.5
WOOD	-1.4	-2.0	-0.3	0.1	0.1	0.0	-0.4	-0.1	-0.6
PAPER	10.3	10.2	-0.1	0.1	0.0	0.0	0.0	0.0	-0.1
BIOSUPPLY	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
BIOCHEMICALS	17.8	42.9	3.9	2.3	-0.1	-0.1	19.3	-0.1	25.2
FEED	4.7	1.4	-0.7	-0.9	0.3	-0.2	-2.2	0.4	-3.3
FERTILISERS	-13.7	-22.6	-4.1	-2.0	-0.6	-0.3	-2.8	0.9	-8.9
FOSSIL FUEL ENERGY	2.9	1.1	-2.2	0.3	0.0	0.0	0.1	-0.2	-1.8
REST OF ECONOMY	16.6	16.8	0.0	-0.1	0.0	0.0	0.1	0.1	0.1

TABLE 30
Output changes (%) between the OL and RS scenarios (2020-2030)

OL VS RS	RS	OL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
AGRICULTURE	1.7	-4.4	-0.7	0.1	-0.6	-1.6	1.2	-4.5	-6.1
FOOD INDUSTRY	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
FISHERY	10.1	17.7	-5.2	-0.3	0.0	-0.1	15.9	-2.8	7.6
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	-20.1	-22.3	0.1	0.3	0.0	-6.1	0.5	3.0	-2.2
WOOD	-1.4	5.3	-2.2	-0.7	0.0	0.3	8.9	0.5	6.7
PAPER	10.3	10.3	-0.1	-0.2	0.0	0.2	0.6	-0.5	0.0
BIOSUPPLY	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
BIOCHEMICALS	17.8	-1.0	9.7	2.6	0.0	-0.9	-35.6	5.6	-18.8
FEED	4.7	-5.2	-4.4	0.9	0.1	-2.9	2.0	-5.6	-9.9
FERTILISERS	-13.7	-35.4	-7.8	-0.5	-0.3	0.5	3.9	-17.5	-21.6
FOSSIL FUEL ENERGY	2.9	-8.6	-0.1	0.1	0.0	0.2	-2.2	-9.6	-11.6
REST OF ECONOMY	16.6	14.9	-0.3	0.5	0.0	0.1	-0.6	-1.4	-1.7

of -2.2% and -0.6%, respectively, leading to lower macro growth (as discussed above). The modelled CAP change has a similar output effect as witnessed in the IL scenario, although less pronounced given the re-distribution of agricultural support payments to Pillar 2 (rural development) objectives.

The multilateral trade deal shock (**Table 30**) provides an opportunity for EU economic growth, although this is not to the benefit of the larger bio-based sectors (i.e., agriculture, food, textiles, wearing apparel and leather). Finally, the full impact of the EU's ambitious GHG emissions reductions can be seen at the sectoral level. As expected, one sees that the repercussions are particularly notable in the fertiliser (-17.5%), and fossil fuels and energy (-9.6%) sectors, particularly given that renewable directive targets are not taken into account. By way of its backward linkage with upstream sectors, the negative impact on petroleum refining has a detrimental effect on the bioenergy (-7.5%), bioeconomy supply (-9.8%), and the residue and feedstock supplying sectors of agriculture and forestry. As a result of general equilibrium primary resource reallocations into relatively cleaner sectors (subject to the economic growth assumptions inherent within the reference scenario), textiles, wearing apparel, leather and biochemical sectors undergo output improvements from the GHG shocks. .Pg 81

Interestingly, the isolated impacts of the projections and world fossil fuel price shocks (unchanged from the RS), have significant incremental impacts for bioenergy activity when comparing with the RS.[30] In the IL scenario (**Table 29**), 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 30**), the increasing mandate pushes up the price of bioeconomy supply and second .Pg 80 .Pg 81

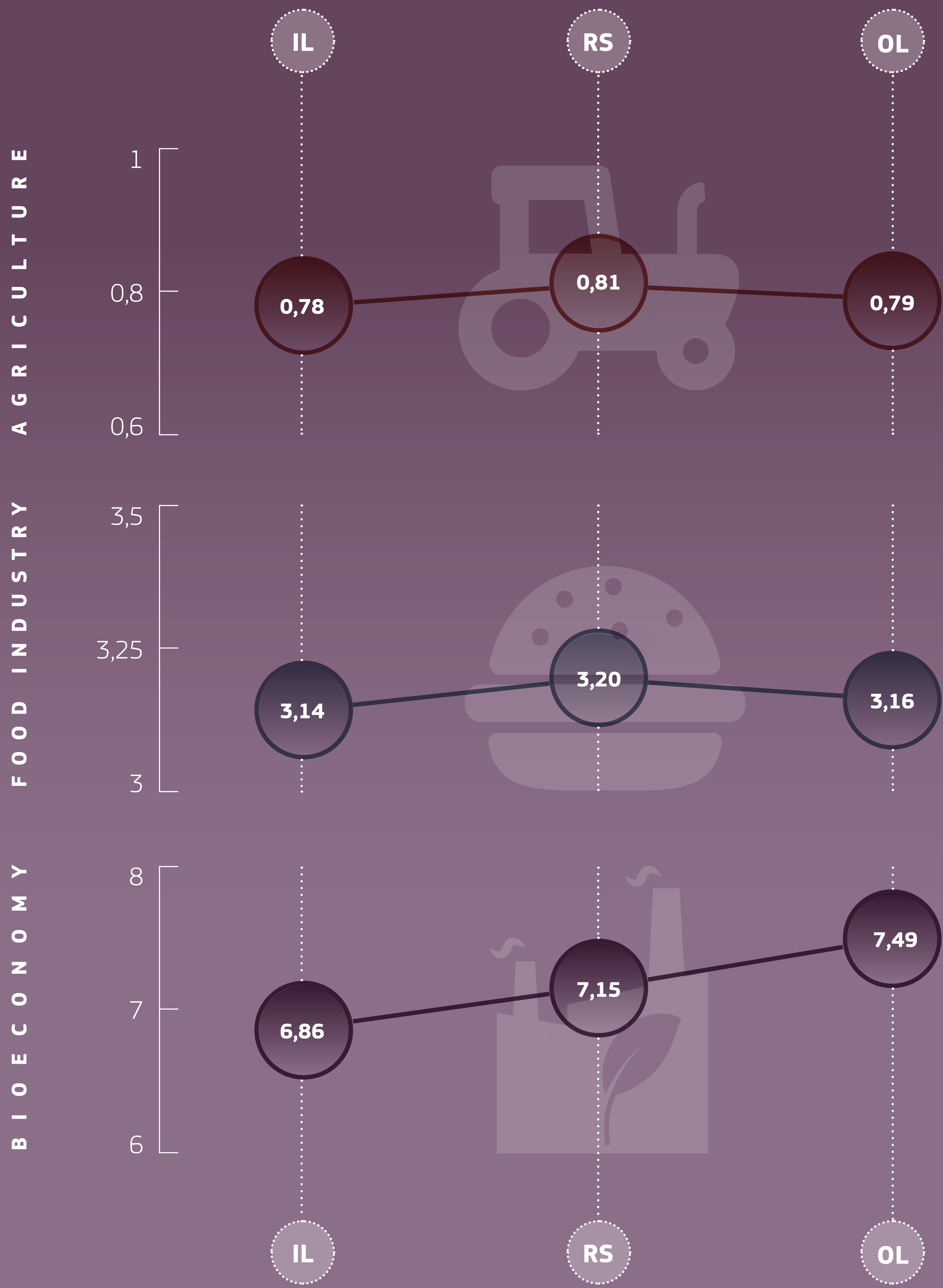
TABLE 31
Bioeconomy output value shares (%) of the EU28 macroeconomy

	2013 RS	2020 RS	2030 RS	2030 IL	2030 OL
AGRICULTURE	1.21	1.00	0.81	0.78	0.79
FOOD INDUSTRY	4.10	3.65	3.20	3.14	3.16
FORESTRY	0.13	0.11	0.10	0.10	0.08
FISHERY	0.08	0.08	0.07	0.07	0.07
TEXTILES	0.55	0.42	0.31	0.32	0.30
WEARING APPAREL	0.47	0.34	0.24	0.25	0.23
LEATHER	0.21	0.13	0.09	0.09	0.08
WOOD	0.69	0.57	0.46	0.46	0.48
PAPER	1.88	1.77	1.62	1.63	1.64
BIOSUPPLY	0.01	0.03	0.03	0.01	0.29
BIOENERGY	0.08	0.11	0.21	0.02	0.35
BIOCHEMICALS	0.00	0.00	0.00	0.00	0.00
BIOECONOMY	9.41	8.23	7.15	6.86	7.49

Source: authors' own calculation

[30] It should also be noted that bioenergy percentage changes are from a smaller base.

TABLE 31
Bioeconomy output value shares (%) of the EU28 macroeconomy



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, North America, China) and better growth prospects, there is more spare capacity for biofuels production.

Finally, examining **Table 31**, the output value shares of each of the EU sectors are compared under each policy scenario. These statistics account for the market value shares corresponding to each activity. As noted in the discussion in section 4.2, the reference scenario trend for the bioeconomy is that of an ever diminishing share of total EU economic activity (reported as 9.4% in 2013 to 7.2% in 2030 in Table 31). Comparing the IL with the RS, this trend is found to have an even steeper decline (6.9% in 2030) with the collapse of the bioenergy sector, and the associated repercussions for bioeconomy supply and primary agriculture. On the other hand, whilst the OL scenario results in relative EU real GDP falls, this scenario arrests the downward trend of the bioeconomy output share (7.5% in 2030). [31] As seen previously, this is largely related to the negative impact on the output of large aggregate sectors of fossil fuels and energy and 'rest', such that the bioeconomy now constitutes a larger share of a smaller EU macro economy. .Pg 82

5.1.3 Bioeconomy employment

Following on from the previous section on bioeconomy output, the bioeconomy employment patterns in thousands of head across the three scenarios are presented in **Table 32**. A large proportion of bio-based employment is centred in the primary agricultural sector. The 4% contraction in IL agricultural output compared with the reference scenario (**Table 29**), results in an estimated further loss of 251,000 workers. In addition, in the IL scenario, employment prospects in the bioenergy sector are also hit (-69,000 workers). Examining the policies .Pg 84 .Pg 80

TABLE 32
EU28 bio-based employment (1000's head) and employment share (%)

	2030 RS	2030 IL vs. RS	2030 OL vs. RS
BIO-BASED EMPLOYMENT	13,550	-384	-306
AGRICULTURE	7,822	-251	-360
FOOD INDUSTRY	3,632	-54	-67
FORESTRY	345	-8	90
FISHERY	157	-5	31
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

Source: authors' own calculation

[31] Note, that despite output rises in forestry (OL vs. RS scenario), the value share falls. This is because the increase in EU foresty supply (owing to residue output from the biofuel mandate) is not met by internal EU domestic demand such that forestry market prices, and the value of output shares, fall.

TABLE 33
Wage rate differences between the IL and RS (2020-2030)

IL VS RS	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
AGRICULTURE	-8.0	-10.6	0.0	-1.3	-0.7	0.0	-1.1	0.5	-2.6
FOOD INDUSTRY	2.3	3.0	0.5	-0.6	0.0	0.1	0.1	0.4	0.7
FORESTRY	4.1	4.6	0.5	-0.6	0.0	0.2	0.1	0.4	0.6
FISHERY	1.3	2.0	0.5	-0.6	0.0	0.1	0.1	0.5	0.6
TEXTILES	2.2	2.9	0.6	-0.6	0.0	0.1	0.1	0.4	0.7
WEARING APPAREL	2.9	3.6	0.5	-0.6	0.0	0.2	0.1	0.4	0.7
LEATHER	1.8	2.6	0.6	-0.6	0.0	0.2	0.2	0.5	0.8
WOOD	2.7	3.3	0.5	-0.6	0.0	0.2	0.1	0.4	0.7
PAPER	1.9	2.6	0.6	-0.6	0.0	0.1	0.1	0.4	0.7
BIOSUPPLY	2.8	3.6	0.8	-0.6	0.0	0.2	0.0	0.4	0.8
BIOENERGY	2.7	3.0	0.1	-0.6	0.0	0.2	0.1	0.4	0.3
BIOCHEMICALS	4.9	5.5	0.4	-0.6	0.0	0.2	0.1	0.4	0.6
FEED	1.7	2.4	0.6	-0.6	0.0	0.1	0.1	0.4	0.7
FERTILISERS	3.3	3.8	0.4	-0.6	0.0	0.2	0.1	0.4	0.5
FOSSIL FUEL ENERGY	2.7	3.4	0.6	-0.6	0.0	0.1	0.1	0.4	0.7
REST OF ECONOMY	1.8	2.5	0.6	-0.6	0.0	0.1	0.1	0.4	0.7

Source: authors' own calculation

TABLE 34
Wage rate differences between the OL and RS (2020-2030)

OL VS RS	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
AGRICULTURE	-8.0	-16.7	-2.1	1.6	-0.3	-1.3	-0.9	-5.6	-8.6
FOOD INDUSTRY	2.3	-2.2	-1.0	1.7	0.0	-0.3	-1.5	-3.4	-4.5
FORESTRY	4.1	-1.0	-1.4	1.8	0.0	-0.3	-1.1	-3.9	-5.0
FISHERY	1.3	-3.8	-0.8	1.9	0.0	-0.4	-2.0	-3.8	-5.1
TEXTILES	2.2	-2.6	-1.0	1.8	0.0	-0.3	-1.7	-3.6	-4.7
WEARING APPAREL	2.9	-2.2	-1.0	1.8	0.0	-0.3	-1.8	-3.8	-5.1
LEATHER	1.8	-3.6	-0.9	1.9	0.0	-0.3	-2.1	-4.0	-5.4
WOOD	2.7	-2.0	-1.0	1.8	0.0	-0.3	-1.4	-3.6	-4.6
PAPER	1.9	-2.5	-1.0	1.7	0.0	-0.3	-1.5	-3.3	-4.4
BIOSUPPLY	2.8	-1.5	-1.4	1.7	0.0	-0.3	-0.8	-3.5	-4.3
BIOENERGY	2.7	-2.2	-1.2	1.8	0.0	-0.3	-1.5	-3.6	-4.9
BIOCHEMICALS	4.9	-0.4	-1.1	1.8	0.0	-0.4	-1.4	-4.1	-5.3
FEED	1.7	-2.9	-0.9	1.8	0.0	-0.3	-1.6	-3.5	-4.6
FERTILISERS	3.3	-1.6	-1.4	1.8	0.0	-0.3	-1.2	-3.7	-4.9
FOSSIL FUEL ENERGY	2.7	-1.7	-1.1	1.7	0.0	-0.3	-1.3	-3.5	-4.4
REST OF ECONOMY	1.8	-2.5	-1.0	1.7	0.0	-0.3	-1.5	-3.3	-4.3

Source: authors' own calculation

which drive output falls in both sectors (**Table 29**), an almost equal proportion of the agricultural employment .Pg 80 reduction is attributed to the removal of Pillar 1 support and the elimination of the biofuel mandates, whilst in the bioenergy sector relative employment falls are heavily associated with the removal of the mandate. This resulting loss of employment from EU agrifood production explains much of the fall in EU bio-based sector employment under this scenario.

Comparing the OL with the RS, the primary agricultural sector sheds even more workers (approximately 360,000), although based on the output drivers discussed in section 5.1.2 (**Table 30**), this is a combination of (in order of magnitude) tougher EU unilateral GHG emissions reductions, the multilateral trade deal and the modelled CAP change (despite agrifood employment rises due to the increasing biofuel mandate and mitigating Pillar 2 CAP initiatives). 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 GHG reductions (**see Table 30**). Despite a very different set of .Pg 81 policy shocks, in both IL and OL scenarios, the bioeconomy employment share is below that of the RS (5.7%), with a value of approximately 5.6% of total EU employment.

The trends in bio-based industry wage rates are presented in **Tables 33 and 34**. Comparing the OL and RS .Pg 85 (**Table 33**), the return to labour is most depressed by the economic slowdown effects associated with (in order of magnitude) (i) further EU GHG reductions and (ii) larger biofuel mandates. Notice that the higher biofuel mandate lessens the wage differential between agricultural and non-agricultural labour since higher biofuel mandates stimulate greater agricultural (crop) production (see **Table 30**). Comparing the IL and RS (**Table 33**), the abolition .Pg 81,85 of the biofuel mandate increases real GDP (**Table 28**), and drives up wages. On the other hand, with the reduced .Pg 77 importance of bioenergy feedstock from agriculture, sectorally trapped agricultural relative wage rates fall (larger wage gap between agricultural and non agricultural labour), which explains why the bioeconomy share of value added in the EU28 is reduced in this scenario (not shown).

5.1.4 Bioeconomy competitiveness

The relative change in the Balassa index of revealed comparative advantage (RCA) or export competitiveness for the EU, North America and Mercosur is presented in **Table 35**, as compared with the calculated values for the RS .Pg 87 in 2030 (see **Table 21**). Comparing the IL and RS, the main impacts are motivated by the elimination of the EU .Pg 64 biofuel policy. With the collapse in internal demand for biofuels as a result of the removal of the subsidy, the EU has significant surpluses of bioeconomy and biofuels to export (dump) on world markets. Thus, as a (now) cheap producer of surplus biofuels, the RCA index rises (0.65 points) notably for the EU. Of even greater significance, Mercosur's increased capacity of biofuels to supply internal EU markets is also now dumped on world markets, resulting in a big RCA increase (8.92 points) for Mercosur. With a significant expansion of biofuel exports from Mercosur and under the auspices of the TTIP agreement, a proportion of world biofuel surpluses are supplied to North American markets, resulting in a competitive RCA index fall of 3.45 points.

Comparing the OL and RS (right hand side of **Table 35**), the multilateral trade deal further evens the playing field for more competitive producers, although the relatively small shifts in RCA indicators reflects the generally low level of applied tariffs on trade. In agriculture, the competitive shifts are (perhaps surprisingly) small, especially in the EU, despite the fact that the non 'greening' component of Pillar 1 CAP support is redistributed into production-

[32] By and large, the RCA changes in the remaining regions are relatively small.

[33] The larger index point changes for bioenergy trade are also due to the fact that the underlying trade flows are a lot smaller than on other bio-based trade.

extensive rural development initiatives and more ambitious GHG limits are imposed. In food trade, the EU faces a small deterioration in its competitiveness (although relatively minor), whilst Mercosur gains a further competitive edge on the other regions. The other key story relates to the bioenergy sectors. Despite the increase in the biofuel mandates, the impact of the further GHG reductions on the upstream EU fossil fuels sector reduces both EU domestic and import demand (principally from Mercosur and North America) for blending.

TABLE 35
Balassa index of revealed comparative advantage (RCA) in the bioeconomy

	IL vs RS scenario in 2030			OL vs RS scenario in 2030		
IL VS RS	EU28	NORTH AMERICA	MERCOSUR	EU28	NORTH AMERICA	MERCOSUR
AGRICULTURE	0.02	-0.14	-0.41	-0.01	0.07	-0.14
FOOD INDUSTRY	0.01	0.03	-0.30	-0.11	0.05	0.57
FORESTRY	-0.02	0.00	0.04	0.21	0.03	-0.07
FISHERY	-0.01	0.00	0.01	0.04	0.01	0.03
TEXTILES	0.01	0.01	0.01	-0.04	-0.02	-0.03
WEARING APPAREL	0.01	0.00	0.00	-0.01	0.00	0.00
LEATHER	0.00	0.00	0.05	-0.01	0.00	-0.05
WOOD	0.00	-0.01	0.05	0.08	0.08	0.01
PAPER	0.00	-0.03	0.07	0.00	0.01	-0.03
BIOSUPPLY	0.65	-0.93	-1.51	-0.11	-0.04	3.63
BIOENERGY	0.38	-3.45	8.92	-0.17	-1.49	-1.63

Source: authors' own calculation

5.2 Sustainable resource usage (2020-2030)

The aim of this section is to ascertain the degree of compatibility of each of the policy narratives with responsible and sustainable resource usage. The discussion not only focuses on fossil fuel and bio-based energy markets, but also broadens the concept of resource usage to encapsulate land, livestock and environmental performance indicators. Once again, a key aim is to understand how different sets of policy shocks drive each of these resource concepts, highlighting were relevant, conflicts or incompatibilities in policy aims.

5.2.1 Energy prices and bioenergy production

In Table 36, we see the evolution of bioenergy production as a value share of total energy supply by country/region. The table illustrates the influence of the EU's biofuel policy, not only for the EU, but also on world markets. With the EU's steady promotion of biofuels in the RS, non EU regions (particularly Mercosur) also increase their bioenergy capacity to meet EU import demands. In the IL scenario, the 2030 share of EU bio-based energy falls from 5.3% in the RS to 0.6%. Moreover, in the IL scenario, the scale of the impact on non-EU countries can be seen by the fall in the bioenergy production shares in all regions, where the most marked effect is in Mercosur. In the OL scenario, by 2030 the EU's bioenergy share of total energy output rises to 9.1%. In addition, with additional EU28 imports of bio-based fuels from competitive producers to help meet its internal policy mandate, both North America (3.3%) and Mercosur (5.9%) continue to witness concomitant increases in their bioenergy output shares by the end of the same period.

Although not shown, the IL and OL scenario related to the modelled CAP changes reduce biomass feedstock, which has a very small, but consistent, negative impact on the EU's bioenergy output share compared with the RS (not shown). Similarly, the trade shocks in both IL and OL scenarios (also not shown) open up cheaper (imported) sources of inputs, which appear to benefit EU bio-based energy sectors, particularly the multilateral trade deal in the OL scenario. Not surprisingly, however, the main drivers for EU bioenergy production shares in the OL scenario, are once again the biofuel mandate (large output increases) and the GHG limits (output decreases).

A comparison of the 2020-2030 trends in EU energy prices with those of the reference scenario (see section 4.4, Table 13) is presented in Table 37. A clear message is the role that EU policy can play in influencing its energy prices. Comparing the IL and RS, the isolated impact of the abolition of the mandate and associated subsidy support, clearly depresses the supply price for bioenergy. The removal of subsidies on blending sector purchases of biofuels implies that the price paid by the blending sector rises, whilst the supply (market) price received by the seller falls (the latter price effect on IL scenario energy output is shown in Table 36). The isolated impact of the loss of the blending subsidy in the IL scenario, reduces the market price in the second generation and bioelectricity sectors by approximately 26% over the period, whilst increasing the final (market) price of petroleum by 1.5%.

.Pg 54
.Pg 91
.Pg 89

On comparing the OL and RS, once again the bioenergy blending mandate, now raised, plays an important role, but in combination with greater GHG emissions reductions. Focusing on the isolated impact of the 2020-2030 biofuel mandate (Table 37), the cost of second generation (thermal and biochemical) biofuels and bioelectricity sectors soars in the OL scenario (approximately 800%). This is the result of a highly ambitious second-generation mandate[34] which generates bottlenecks in the supply of feedstock from the infant industry activities of plantations, pellets and residues. As the subsidy rises to meet this mandate, the (blended) petroleum price falls (-1.5%), whilst a combination of substitution away from fossil fuels and an economic slowdown (negative real income) effect from the biofuel policy, reduces prices in other energy commodities. [35]

.Pg 91

The other influencing factor in the OL scenario is the additional reduction in EU28 GHG emissions limits. 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%), when compared with the RS.[36] The resulting output contraction in these

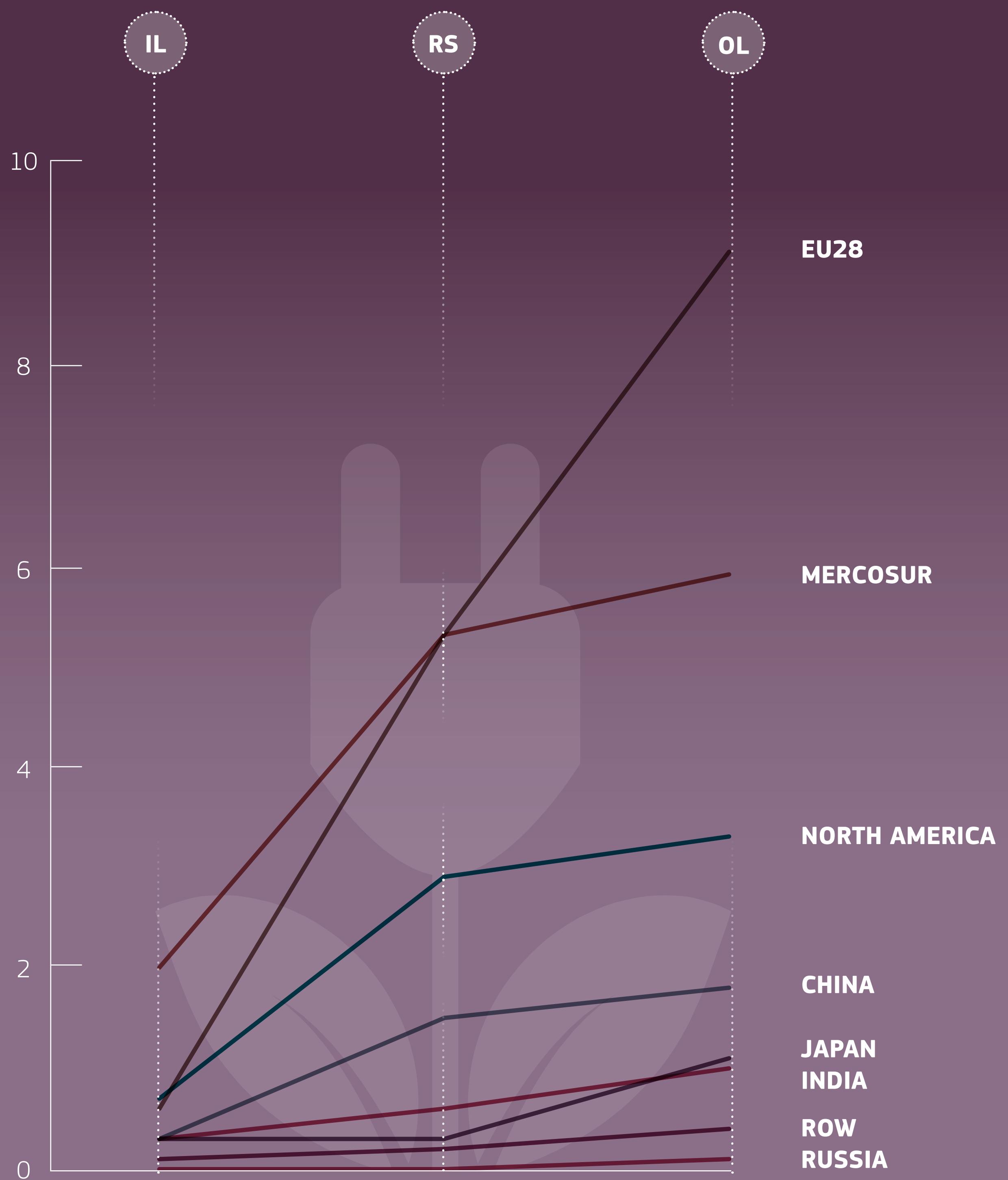
TABLE 36
Output value share of bioenergy (%) in total energy production

	2013 RS	2020 RS	2030 RS	2030 IL	2030 OL
EU28	1.8	2.9	5.3	0.6	9.1
NORTH 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

Source: authors' own calculation

[34] In this scenario, it is raised from 1.5% to 5% - see Table 6.
[35] It was shown in section 5.1.1, that increasing the mandate in the OL scenario reduces relative growth in the EU compared with the RS.
[36] In all three sectors, it is assumed that substitution of capital for more expensive fossil fuels is possible, although in petroleum, there is also the possibility to substitute for bio-based fuels, which explains the small price rise compared with electricity and gas sectors.

TABLE 36
Output value share of bioenergy (%) in total energy production (2030)



.Pg 81 refining and processing energy industries (see **Table 30**) from higher EU GHG emissions cuts, reduces derived demand for crude oil, gas, and bio-based energy inputs, thereby depressing market prices in these intermediate sectors. In the case of coal, which is used intensively in electricity generation and is assumed to be relatively less substitutable, the result is that electricity demand for coal falls by less.

TABLE 37
Changes in energy prices compared with the RS (2020-2030)

IL VS RS	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
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
BIOETHANOL	-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
BIOELECTRICITY	-15.1	-48.1	-2.4	-4.9	0.1	-0.2	-25.8	0.3	-33.0
THERMAL 2ND-GEN	-15.2	-48.4	-2.7	-4.8	0.1	-0.3	-25.8	0.3	-33.2
BIOCHEM 2ND-GEN	-15.3	-49.6	-2.8	-5.0	0.1	-0.3	-26.7	0.3	-34.3

OL VS RS	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
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
BIOETHANOL	-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
BIOELECTRICITY	-15.1	306.4	-332.3	-2.8	-0.7	2.9	803.5	-149.2	321.5
THERMAL 2ND-GEN	-15.2	301.2	-324.5	-2.8	-0.7	2.8	787.4	-145.9	316.3
BIOCHEM 2ND-GEN	-15.3	312.8	-336.8	-2.9	-0.7	2.9	817.0	-151.4	328.1

Source: authors' own calculation

5.2.2 Land markets

5.2.2.1 Land usage

Table 38 presents changes in land usage across different regions and policy scenarios compared with the RS. In both IL and OL scenarios, land usage falls relative to the RS, although by less in the OL policy world. In the case of the EU, the part-worth shocks reveal that the modelled CAP change has the most significant impact in reducing land usage. The elimination of those Pillar 1 decoupled payments not related to 'greening' in the IL scenario, reduces the usage of (marginal) land by 4.2%. In the OL scenario, land abandonment is smaller (-2.1%) compared with the RS since a proportion of the reduction in Pillar 1 payments are redistributed back into land related Pillar 2 rural development measures (i.e., agro environmental and least favoured areas (LFA) schemes).

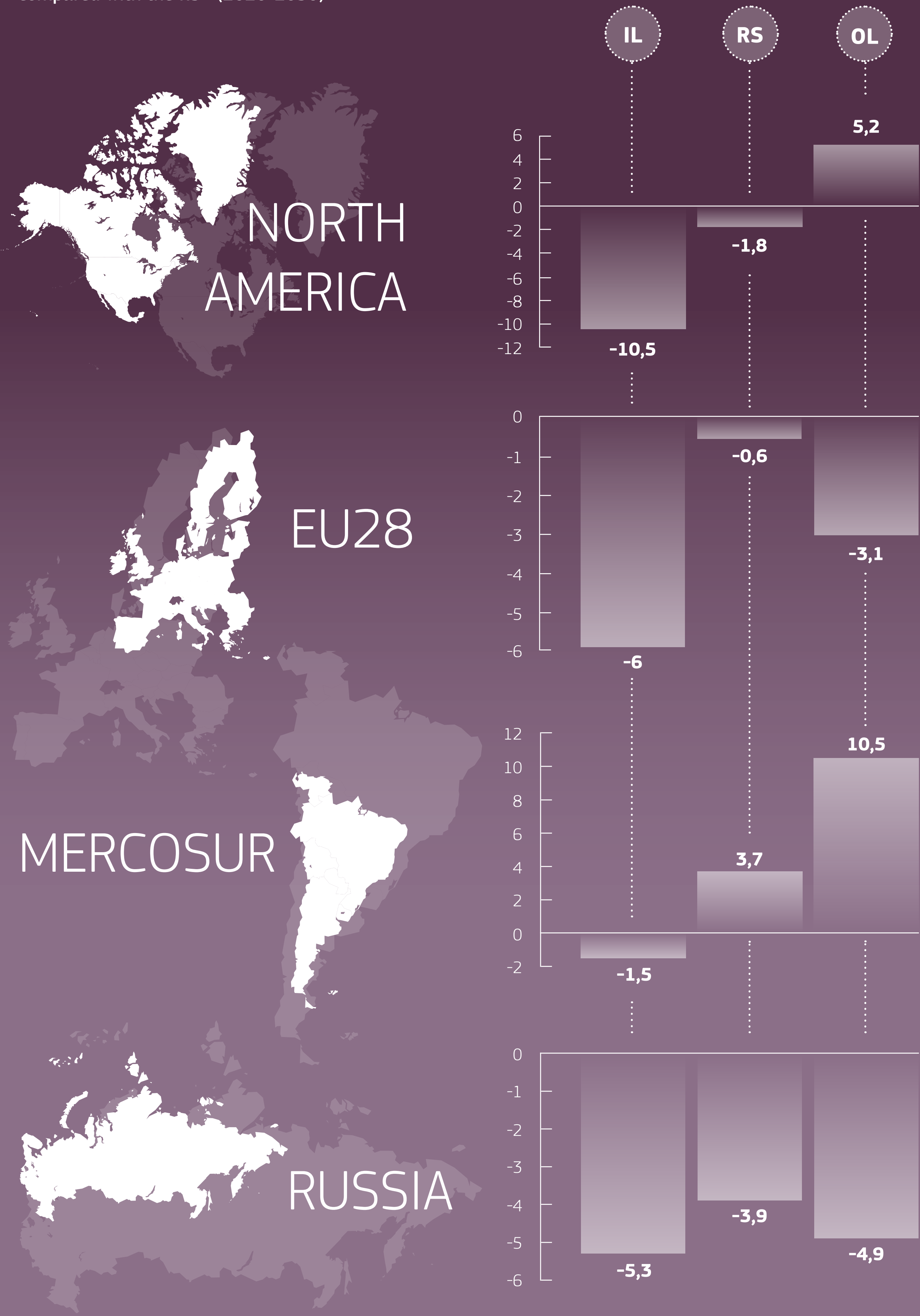
TABLE 38
Changes in global land use by regions compared with the RS (2020-2030)

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
IL VS RS	RS	IL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
EU28	-0.6	-6.0	-0.6	-0.2	-4.2	0.0	-0.3	-0.1	-5.4
NORTH AMERICA	-1.8	-10.5	-6.8	3.1	0.2	0.3	-2.4	-3.1	-8.6
MERCOSUR	3.7	-1.5	-2.9	-1.5	0.2	0.0	-2.0	1.0	-5.2
RUSSIA	-3.9	-5.3	0.1	-1.1	0.2	0.0	-1.0	0.4	-1.4
CHINA	1.1	1.0	0.0	-0.1	0.0	0.0	-0.1	0.0	-0.1
INDIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JAPAN	-7.0	-7.7	0.1	-0.6	0.0	0.1	-0.5	0.2	-0.7
ROW	1.2	0.8	0.3	-0.6	0.1	0.0	-0.3	0.1	-0.4

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
OL VS RS	RS	OL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
EU28	-0.6	-3.1	-0.6	-0.2	-4.2	0.0	-0.3	-0.1	-5.4
NORTH AMERICA	-1.8	5.2	-6.8	3.1	0.2	0.3	-2.4	-3.1	-8.6
MERCOSUR	3.7	10.5	-2.9	-1.5	0.2	0.0	-2.0	1.0	-5.2
RUSSIA	-3.9	-4.9	0.1	-1.1	0.2	0.0	-1.0	0.4	-1.4
CHINA	1.1	1.2	0.0	-0.1	0.0	0.0	-0.1	0.0	-0.1
INDIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JAPAN	-7.0	-8.2	0.1	-0.6	0.0	0.1	-0.5	0.2	-0.7
ROW	1.2	0.9	0.3	-0.6	0.1	0.0	-0.3	0.1	-0.4

Source: authors' own calculation

TABLE 38
Changes in global land use by regions compared with the RS (2020-2030)



The impacts of the trade shocks on EU land usage in the IL and OL scenarios are found to be minor, although the multilateral trade deal in the OL scenario implies a significant relative land expansion for Mercosur (6.1%). The rising biofuel mandate in the OL scenario drives up EU land usage in the EU (1.6%), but also in competitive supplier countries such as North America (1.9%) and Mercosur (5.8%), whilst the abolition of the EU mandate in the IL scenario has the expected opposite effects. Perhaps surprisingly, it was found that in absolute terms, higher GHG emissions controls in the OL scenario have a lesser impact on EU agricultural land usage than either that of the modelled CAP change or the biofuel mandates (see **Table 38**). .Pg 92

In **Table 39**, a quantification of the land use changes reported above is presented in squared kilometres (km2) for a selection of regions. Owing to the combination of factors discussed above, over the 2020-2030 period, the relative percentage reductions in EU28 land reported in **Table 33** correspond to land area falls of -100,498 .Pg 94 .Pg 85

TABLE 39
Land use changes (km2) by regions compared with the RS

	GERMANY	FRANCE	ITALY	SPAIN	EU28	NORTH AMERICA	MERCOSUR	CHINA	ROW
2013 RS									
AGRICULTURE	180,414	297,009	139,631	247,239	1,890,320	4,682,025	4,988,271	5,525,745	51,857,122
BIOSUPPLY	178	35	36	18	658	965	130	98	3,246
TOTAL	180,591	297,045	139,667	247,258	1,890,978	4,682,989	4,988,400	5,525,842	51,860,368
2020 RS									
AGRICULTURE	174,864	293,337	136,850	245,486	1,858,526	4,582,882	5,004,567	5,700,564	51,058,155
BIOSUPPLY	293	58	58	31	1,068	1,091	279	105	4,537
TOTAL	175,157	293,394	136,907	245,517	1,859,594	4,583,973	5,004,846	5,700,669	51,062,693
2030 RS									
AGRICULTURE	172,318	293,509	135,663	244,892	1,847,800	4,498,385	5,189,821	5,765,684	514,59,588
BIOSUPPLY	300	58	60	32	1,100	1,085	522	101	4,865
TOTAL	172,618	293,566	135,722	244,924	1,848,900	4,499,470	5,190,343	5,765,785	51,464,453
IL VS RS 2030									
AGRICULTURE	-14,989	-13,497	-7,521	-5,878	-99,791	-386,861	-269,871	-5,247	-994,827
BIOSUPPLY	-150	-29	-46	-17	-707	-720	-379	-70	-3,130
TOTAL	-15,139	-13,526	-7,567	-5,895	-100,498	-386,954	-269,898	-5,317	-997,957
OL VS RS 2030									
AGRICULTURE	-4,115	-6,375	-3,406	-1,722	-42,487	319,473	334,606	2,550	477,914
BIOSUPPLY	247	45	43	24	841	1,109	4,373	69	8,163
TOTAL	-3,868	-6,330	-3,363	-1,698	-41,646	320,581	338,979	2,619	486,076

Source: authors' own calculation

.Pg 92

km2 (IL) and -41,646km2 (OL). In North America and Mercosur, the relative land use result reported in the OL scenario (**Table 38**) is translated as an expansion of land area equivalent to 320,581 km2 (North America) and 338,979km2 (Mercosur).

The relative trends and drivers of land yields for cereals, oilseeds and horticultural crops in both IL and OL scenarios are presented in **Table 40**. The modelled CAP changes in both scenarios increases average land yields (output divided by land usage) since the output fall in agriculture is minor due to the decoupled nature of Pillar 1 payments. The positive yield effect of the CAP is stronger in the IL scenario since in the OL scenario, a greater degree of marginal land is retained owing to the redistribution of Pillar 1 payments into land extensification Pillar 2 schemes (i.e., agri environmental and LFAs).

TABLE 40
EU28 land yield changes (%) compared with the RS (2020-2030)

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
IL VS RS	RS	IL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
WHEAT	3.4	4.3	-0.1	-1.5	4.2	-0.5	-1.3	0.1	0.9
GRAINS	3.7	5.4	0.0	-0.9	3.3	-0.2	-0.6	0.1	1.7
OILSEEDS	13.2	-15.4	-12.6	-3.2	6.4	0.0	-19.5	0.3	-28.6
RAW SUGAR	4.9	-2.0	-5.4	-5.0	13.0	-0.3	-8.7	-0.4	-6.9
HORTICULTURE	0.4	6.1	1.7	0.3	3.3	0.0	0.5	-0.1	5.8

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
OL VS RS	RS	OL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
WHEAT	3.4	3.0	0.2	0.2	1.9	1.2	-2.3	-1.6	-0.4
GRAINS	3.7	2.6	0.8	-0.2	2.0	-0.5	-1.7	-1.5	-1.1
OILSEEDS	13.2	2.6	-4.8	-3.7	1.8	-0.1	-3.2	-0.5	-10.6
RAW SUGAR	4.9	-1.4	-5.3	-4.9	6.0	-1.1	-2.0	1.0	-6.3
HORTICULTURE	0.4	6.3	3.0	0.4	1.5	0.1	-0.5	1.4	5.9

Source: authors' own calculation

TABLE 40
EU28 land yield changes (%) compared with the RS (2020-2030)

.Pg 95 In **Table 40,** the limited gain in productivity from greater uptake of marginal EU land is in evidence when examining the role of the higher biofuel blending mandate in the OL scenario. In all crops, there is a small, but unambiguous, negative impact on land yields. Drilling down further into the results reveals that the increases in feedstock crops for biofuels are slower than the associated rise in land uptake. [37] The elimination of the blending mandate and associated subsidies in the IL scenario leads to an aggressive production fall, with associated yield declines, particularly in oilseeds (used in first generation biodiesel) and raw sugar (used in first generation bioethanol). [38]

The impact of the regional (IL scenario) and multilateral (OL scenario) trade shocks on land yields is relatively small and is a function of the relative competitiveness of EU producers with respect to all those third country trade partners with whom tariff are removed/reduced.
Finally, higher EU GHG targets in the OL scenario impact negatively on cereals land yields. This is due to an indirect effect, since cereals are used more intensively as feeds in the livestock sectors, which are hit by imposed GHG emissions reductions (from manure management practises and enteric fermentation). In addition, there is a direct effect, since rice cultivation (aggregated within the 'other grains' sector) is a further source of methane emissions which is also impacted upon by the GHG emissions reductions.

5.2.2.2 Land Rents

.Pg 98 The situation for relative changes in real land rents is presented in **Table 41**. For the EU, the differences between the RS and both the IL and OL scenarios are very much influenced by the isolated impact of the modelled CAP changes. With Pillar 1 decoupled payments entirely capitalised into the value of land, the removal of CAP payments in the IL and OL scenarios leads to real land rent fall of 29% and 17%, respectively. In the OL scenario, the 17% fall in real land rents is the net result of a 29% fall associated with the removal of Pillar 1 decoupled CAP payments (not shown), and the redistribution of a proportion of CAP support into land following Nowicki et al. (2009) as Pillar 2 agri-environmental and LFA schemes (+12%, not shown).

.Pg 98 As expected, in **Table 41**, the removal of the biofuels policy (IL scenario) has a relatively detrimental impact on EU real land rents, whilst an opposite effect occurs in the OL scenario with the raising of blending limits (12.5%). In the non EU regions, the abolition of the EU's biofuel mandate in the IL scenario leads to relative falls in real land rents as EU import demand for biofuels drops dramatically, whilst relative increases in EU biofuels imports in the OL scenario appear to benefit Mercosur, North American and (curiously) Japanese real land rents. In the OL scenario, the EU's macro slowdown and resulting loss of competitiveness due to the additional GHG emissions reductions shocks, further depresses real land rents (-4.4%). Finally, whilst the multilateral trade deal in the OL scenario only has a small depressing effect on land rents in the EU, it generates a significant detrimental impact on real land rents in India and Japan, whilst offering competitive trade driven real land rent rises in Mercosur, North America and China.

[37] This result can also be seen at the aggregate level by comparing the EU agricultural output rise of 1.2% in the OL scenario from the rising biofuel mandate (Table 30), compared with the uptake of land by 1.6% associated with the same policy shock (Table 38).
[38] Once again, looking at the impact of the elimination of the EU's biofuel policy, the validity of this result can be checked by comparing the EU agricultural output fall of -1.2% (Table 29) compared with the associated land use fall of -0.3% (Table 38).

TABLE 41
EU28 real land rent changes (%) compared with the RS (2020-2030)

IL VS RS	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
EU28	-3.9	-38.1	-1.6	-1.9	-28.7	-0.2	-1.8	0.0	-34.2
NORTH AMERICA	-2.1	-11.0	-7.9	4.4	0.1	0.4	-2.1	-3.8	-8.8
MERCOSUR	2.7	-1.0	-1.8	-1.1	0.1	0.0	-1.4	0.4	-3.8
RUSSIA	-1.1	-1.4	0.0	-0.3	0.1	0.0	-0.3	0.1	-0.4
CHINA	32.9	29.5	-0.2	-2.6	0.5	-0.4	-1.7	1.0	-3.5
INDIA	49.5	48.6	-0.2	-0.6	0.2	0.0	-0.4	0.2	-0.8
JAPAN	-45.7	-48.4	1.8	-3.1	0.2	0.3	-2.9	1.0	-2.7
ROW	5.5	4.3	0.4	-1.5	0.4	-0.1	-0.9	0.6	-1.2

OL VS RS	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
EU28	-3.9	-22.3	-7.9	-1.3	-16.7	-0.6	12.5	-4.4	-18.5
NORTH AMERICA	-2.1	6.8	10.8	-15.5	0.2	1.4	1.1	11.1	9.0
MERCOSUR	2.7	8.1	-4.6	0.1	0.1	4.6	4.5	0.6	5.4
RUSSIA	-1.1	-1.3	-0.6	0.3	0.0	-0.2	0.3	-0.1	-0.3
CHINA	32.9	34.6	-3.1	3.9	0.3	1.3	-0.9	0.2	1.7
INDIA	49.5	41.0	-1.2	0.5	0.1	-7.5	-0.7	0.5	-8.4
JAPAN	-45.7	-50.1	-5.3	1.3	0.1	-13.2	16.7	-3.9	-4.4
ROW	5.5	2.1	-2.0	2.1	0.2	-2.2	-0.4	-1.0	-3.4

Source: authors' own calculation

5.2.2.3 Land usage in biofuels

To examine the debate on how policy influences rival uses of biomass (i.e., feed vs. fuel), **Table 42** presents the proportion of land devoted to different sources (first generation, second generation) of biofuels production in each of the regions in 2030. Note that first generation land usage far outstrips that of second generation. 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 RS. By 2030, compared with a 3.3% share of EU land in the RS, 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 has negative repercussions for biofuel land usage in Mercosur and North America.

TABLE 42
Share (%) of land devoted to 1st and 2nd generation biofuels by narratives

	EU28	NORTH AMERICA	MERCOSUR	RUSSIA	CHINA	INDIA	JAPAN	ROW
2030 RS								
BIOETHANOL (1ST-GEN)	1.25	3.47	1.01	0.00	0.09	0.00	0.00	0.02
BIODIESEL (1ST-GEN)	2.04	2.85	1.69	0.01	1.02	0.00	0.00	0.13
BIOCHEM (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
THERMAL (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TOTAL	3.29	6.32	2.70	0.01	1.10	0.00	0.03	0.15
2030 IL VS. RS								
BIOETHANOL (1ST-GEN)	-1.17	-2.33	-0.66	0.00	-0.05	0.00	0.00	-0.02
BIODIESEL (1ST-GEN)	-1.86	-2.49	-0.90	-0.01	-0.83	0.00	0.00	-0.11
BIOCHEM (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
THERMAL (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
TOTAL	-3.03	-4.82	-1.57	-0.01	-0.88	0.00	-0.03	-0.12
2030 OL VS. RS								
BIOETHANOL (1ST-GEN)	-0.72	-0.25	-0.11	0.00	-0.01	0.00	0.03	0.00
BIODIESEL (1ST-GEN)	-0.98	-0.77	0.12	0.02	0.01	0.00	0.00	0.00
BIOCHEM (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
THERMAL (2ND-GEN)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TOTAL	-1.70	-1.02	0.01	0.02	0.00	0.00	0.04	0.00

Source: authors' own calculation

In the OL scenario, one might expect, a priori, to find increased land shares devoted to biofuel production due to the assumed increases in the blending mandates. The model simulation, however, shows that the negative impact of the EU's additional GHG emissions reductions reduces derived demand for bio-based (and fossil based) fuels by the blending (petroleum) sector, leading to lower land usage compared with the reference scenario. Once again, the drop in biodiesel land usage compared with the reference scenario is greater than that experienced in first generation bioethanol due to biodiesel's greater input intensity in the EU blending industry.[39] 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.

[39] Based on a calculation from the underlying dataset.

5.2.3 Environmental indicators

In the IL scenario, regional GHG emissions are assumed to follow the same path as the RS, whilst in the OL scenario the EU honours a commitment to reduce its GHG emissions unilaterally by 43% below 1990 levels.[40] Although in principle, the EU's total emissions reductions in the IL and RS are identical, a comparison of the two scenarios in 2030 (Table 43) still reveals perturbations in the allocation of emissions changes on a sector-by-sector basis, largely based on the impact of additional biofuel and CAP policy shocks on the agricultural sector within the IL scenario. In particular, with a relative contraction in more emissions intensive agricultural, fertiliser and fossil fuel output in the IL scenario (Table 29), relative GHG emissions in these sectors also decline compared with the RS (Table 43), which is 'compensated' by increases in GHG emissions in the EU's aggregate non bio-based sector, 'rest'.

A comparison of the OL and RS shows, as expected, further GHG emissions reductions in many EU sectors (Table 43). The emissions falls are particularly prevalent in the fossil fuels and energy sector, as well as on final demands (largely transport demand), whilst further important falls are also witnessed in the fertiliser sector and in primary agriculture. With strong emissions reductions in these sectors, there is existing 'slack' for those remaining (relatively cleaner) bioeconomy activities, whose GHG emissions are largely unaffected. Indeed, in the case of EU forestry, fishing and wood activities, these sectors even exhibit GHG emission rises.

TABLE 43
Index (2013=100) of EU28 greenhouse gas emissions by policy narrative

	2013 RS	2020 RS	2030 RS	2030 IL	2030 OL	GHG mt CO2e 2020
AGRICULTURE	100	97.8	95.7	93.1	82.0	352.9
FOOD INDUSTRY	100	98.8	96.7	99.0	97.9	50.8
FORESTRY	100	93.3	83.1	87.5	100.4	3.6
FISHERY	100	97.4	88.0	94.5	98.2	6.8
TEXTILES	100	85.5	73.1	75.1	71.7	4.7
WEARING APPAREL	100	81.4	66.5	69.1	65.0	1.8
LEATHER	100	69.5	48.9	50.7	47.6	0.8
WOOD	100	92.1	81.3	85.3	92.2	3.3
PAPER	100	101.8	103.3	105.1	104.8	33.0
FERTILISERS	100	75.8	59.7	53.8	43.4	11.0
FOSSIL FUEL ENERGY	100	65.0	56.8	49.5	24.8	935.1
REST OF ECONOMY	100	106.9	108.4	114.7	102.1	1,934.1
FINAL DEMANDS	100	100.4	96.1	96.0	69.1	627.2
EU28 TOTAL	100	91.1	88.1	88.1	69.9	3,965.0

Source: authors' own calculation

[40] In the EC (2015) reference from where the more severe EU28 GHG emissions cut is taken, it forms part of a 'Global Mitigation Scenario' designed to keep global temperature changes below the 2ºC threshold.

As a further indicator of sustainable resource usage, some discussion is also reserved for the change in emissions of carbon dioxide equivalents (CO2e) per hectare of land use in the EU. Overall, the trend in the RS is that tonnes of CO2e emitted (tCO2e) per km2 of land fall only slightly from 191 tCO2e/km2 in 2013 to 187 tCO2e/km2 by 2030 (not shown). In the IL scenario, by 2030 this statistic rises back up to 2013 levels (192 tCO2e/km2), whilst in the OL scenario, there is an estimated further fall to 164 tCO2e/km2 by 2030 (not shown). Examining the drivers of these trends (**Table 44**), in the OL scenario, it is clear that the additional GHG emissions reductions largely explain this fall. On the other hand, assumed changes in CAP policy increase the ratio of CO2e emissions per hectare since the removal of (marginal) land from production appears to be more pronounced than the reduction in agricultural emissions associated with the elimination of a (decoupled) market support payment. In the OL scenario, this trend is weakened because of higher land retention resulting from simultaneous increases in Pillar 2 extensification payments.

The IL and OL scenarios are similar to the scenarios of the ECAMPA project (Perez-Dominguez et al., forthcoming) which assume a 15 and 20% emission reductions target for the agricultural sector. While the more detailed sectorial results might diverge due to the methodological differences, the overall trend (reduction in emissions associated to reduction in production) is consistent between the two modelling exercises.

TABLE 44

EU28 changes in CO2 emissions per hectare (%) compared with the RS (2020-2030)

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
IL VS RS	RS	IL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
CO2/KM2	-1.6	1.2	0.9	-0.9	3.3	-0.2	-0.4	0.2	2.8

			DECOMPOSITION BY SHOCKS VS RS (2020-2030)						
OL VS RS	RS	OL	PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
CO2/KM2	-1.6	-13.3	-1.8	1.5	1.2	-3.7	1.4	-10.2	-11.7

Source: authors' own calculation

GRAPHICAL REPRESENTATION OF TABLE 43

Index (2013=100) of EU28 greenhouse gas emissions by policy narrative by 2030

IL VS RS	RS - IL	RS	RS - OL
AGRICULTURE	-2,6	95.7	-13,7
FOOD INDUSTRY	2,3	96.7	1,2
FORESTRY	4,4	83.1	17,3
FISHERY	6,5	88.0	10,2
TEXTILES	2	73.1	-1,4
WEARING APPAREL	2,6	66.5	-1,5
LEATHER	1,8	48.9	-1,3
WOOD	4	81.3	10,9
PAPER	1,8	103.3	1,5
FERTILISERS	-5,9	59.7	-16,3
FOSSIL FUEL ENERGY	-7,3	56.8	-32
REST OF ECONOMY	6,3	108.4	-6,3
FINAL DEMANDS	-0,1	96.1	-27
EU28 TOTAL	0	88.1	-18,2

GHG mt CO2e 2020

EU28 TOTAL 2030 IL
88,1

EU28 TOTAL 2030 RS
88,1

EU28 TOTAL 2030 OL
69,9

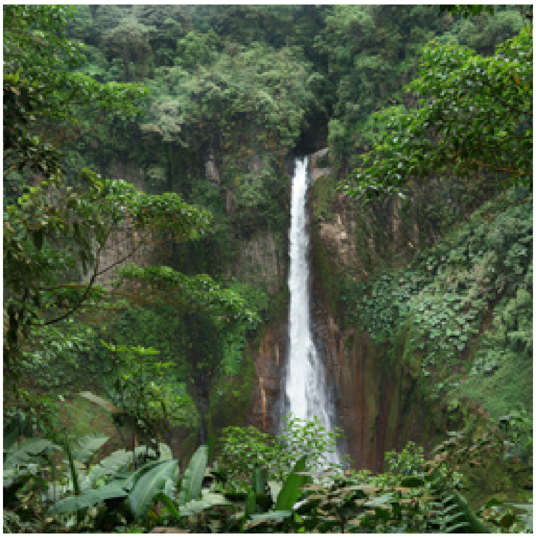
352.9	AGRICULTURE
50.8	FOOD INDUSTRY
3.6	FORESTRY
6.8	FISHERY
4.7	TEXTILES
1.8	WEARING APPAREL
0.8	LEATHER
3.3	WOOD
33.0	PAPER
11.0	FERTILISERS
935.1	FOSSIL FUEL ENERGY
1,934.1	REST OF ECONOMY
627.2	FINAL DEMANDS
3,965.0	EU28 TOTAL

Interestingly, higher biofuel mandates in the OL scenario, which seek to promote a sustainable form of bioenergy supply, also have detrimental environmental impacts, producing higher levels of CO2e per hectare. This is despite the fact that the higher biofuel mandate driver also slightly reduces land yields per hectare (**Table 40**), which implies that in agriculture, emissions rise by proportionately more than output (and therefore, land usage). In the IL scenario, where biofuel mandates are abolished, agricultural output falls, land yields fall, and CO2e per hectare also falls. Finally, the trade drivers reduce CO2e per hectare as a result of import substitution effects, where under a multilateral trade deal (OL scenario), this effect is clearly stronger. .Pg 95

Finally, the changes in stocking densities for cattle and raw milk sectors are presented in **Table 45**.[41] Comparing the IL and OL scenarios with the RS, the isolated impact of removing Pillar 1 decoupled payments increases stocking densities due to the reduction in associated land usage. Once again, the increase in stocking densities is less in the OL scenario, since more (marginal) land is retained within agriculture though concomitant increases in rural development Pillar 2 programmes.

In both IL and OL scenarios, the trade shocks appear to reduce stocking densities relative to the RS as EU meat and dairy trade competitiveness is threatened. As expected this detrimental impact is stronger under the multilateral trade reform of the OL scenario vis-à-vis the neighbourhood/regional trade policy approach adopted in the IL scenario.

Additional EU GHG emissions reductions in the OL scenario compared with the RS reduce cattle production and thus significantly reduce stocking densities in cattle and raw milk sectors (no technological adaptation is assumed). Finally, in the OL scenario, the biofuel mandate has the effect of increasing stocking densities in livestock sectors by channelling land toward biofuel feedstock (cropping) activities. The opposite effect is observed in the case of the IL scenario, where biofuel mandates are abolished.



[41] In this study, to characterise the intensiveness of pigs and poultry production systems, it is assumed that this sector does not vary its land uptake. In modelling terms, in the benchmark database the capitalised value of land is subsumed within the capital factor used by the pigs and poultry industry.

TABLE 45
EU28 stocking density changes (%) compared with the RS (2020-2030)

IL VS RS	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
CATTLE	0.0	-0.2	-0.6	-1.7	2.2	-0.2	-0.9	1.0	-0.2
RAW MILK	2.1	3.5	0.0	-0.5	2.8	-0.5	-0.5	0.1	1.4

OL VS RS	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE OL VS RS
CATTLE	0.0	-18.2	-3.9	2.8	0.5	-4.9	3.4	-16.3	-18.3
RAW MILK	2.1	-0.4	-0.1	0.0	1.5	-1.6	0.3	-2.6	-2.5

Source: authors' own calculation

5.3 Food security (2020-2030)

At its inception, a central tenet of the European Union (né European Economic Community - 1957) was the creation of a strong agricultural sector to ensure prosperity by fostering self-sufficiency after the food shortages of the Second World War. As a result of over stimulation of agricultural output, the emphasis of agricultural policy in later years became more entrenched in how to dispose of food surpluses. Yet in the 21st century, the issue of food security is once again on the policy agenda, largely in response to Malthusian fears of rapid population growth. A further view that has gained considerable traction within the scientific community is the potentially detrimental impact of rising temperatures on agricultural yields and soil degradation. In this context, the following sections focus on the EU's place in the world as a net source of food supply/demand under each of the policy narratives. As in previous sections, a key area of the research examines how, and the extent to which, specific policy shocks encourage or discourage EU food security. The main metrics to measure food security focus on food production and prices, self-sufficiency and trade; economic development and nutrition.

5.3.1 Food production and prices

For the decade 2020-2030, Table 46 presents the changes in EU agricultural and food output and consumer prices for the three policy narratives. In terms of production, the underlying result is that compared with the RS, in the IL and OL scenarios, there are falls in agriculture and food production. For example, in primary agriculture, the output fall is -4.0% and -6.1% for IL and OL, respectively. In the food sector, the corresponding output falls are -2.2% and -3.6%, respectively. Examining the decomposition of this result, the policy reform shocks relating to the CAP and trade policy generate, as expected, small reductions in agrifood production within the EU. In the case of the modelled CAP changes, output falls in the IL and OL scenarios are very minor since agricultural policy is largely classified as non distortionary (decoupled). In the OL scenario, relative agricultural (and therefore food) production falls are lessened since reductions in market support are partly compensated by rural development (Pillar 2) extensification payments. In the case of the trade shocks, the EU's neighbourhood and regional policy (IL

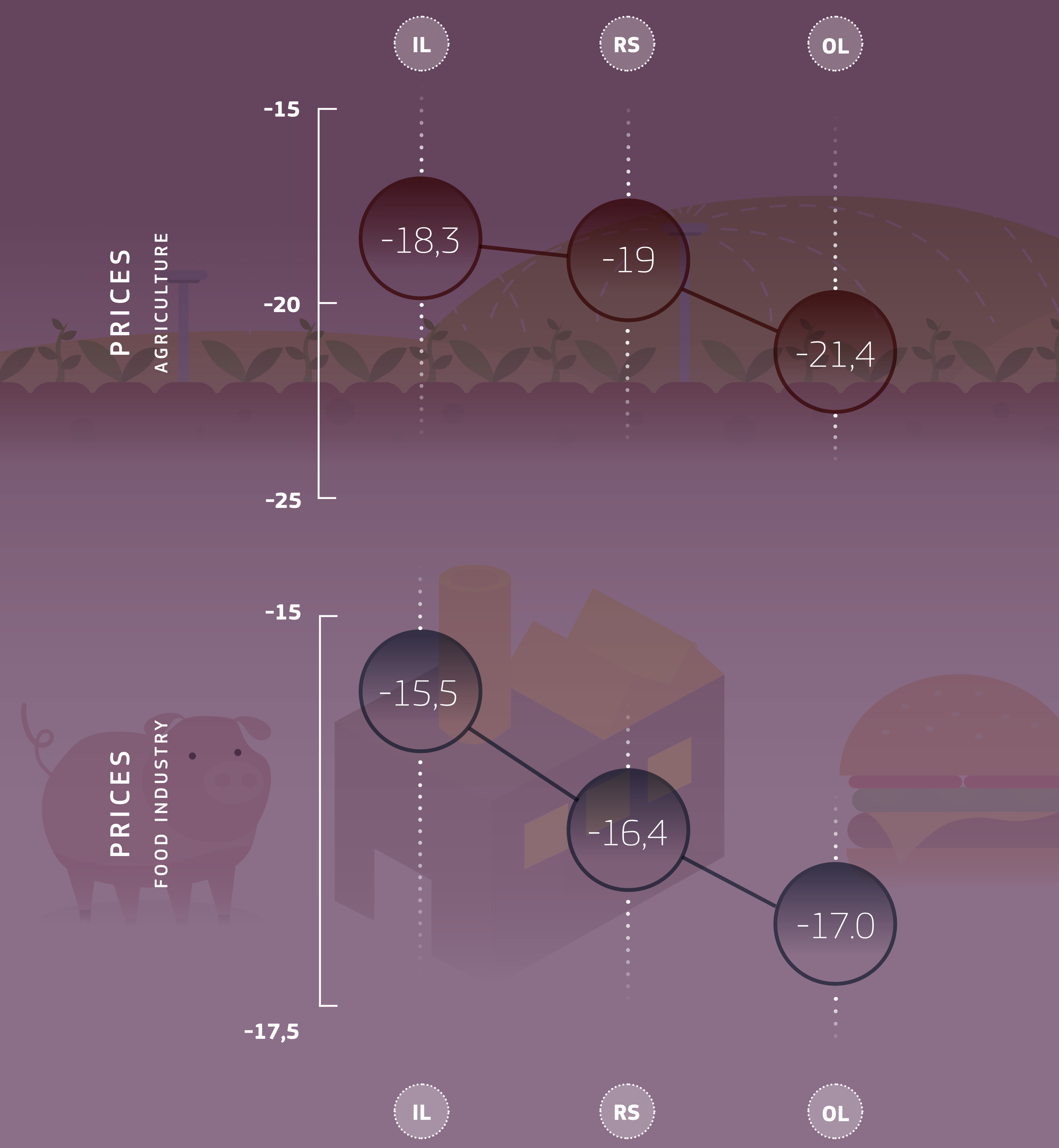
TABLE 46
Change (%) in EU agrifood output and consumer prices compared with the RS (2020-2030)

OUTPUT	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						DIFFERENCE IL VS RS
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	
IL VS. RS									
AGRICULTURE	1.7	-2.3	-0.8	-0.9	-1.0	-0.1	-1.2	0.0	-4.0
FOOD INDUSTRY	7.9	5.6	-0.7	-0.4	-0.2	-0.2	-0.7	0.0	-2.2
OL VS. RS									
AGRICULTURE	1.7	-4.4	-0.7	0.1	-0.6	-1.6	1.2	-4.5	-6.1
FOOD INDUSTRY	7.9	4.3	-0.8	-0.4	-0.2	-1.8	1.2	-1.6	-3.6

PRICES	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030)						DIFFERENCE OL VS RS
			PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	
IL VS. RS									
AGRICULTURE	-19.0	-18.3	0.8	-1.0	0.9	0.0	-0.5	0.5	0.7
FOOD INDUSTRY	-16.4	-15.5	1.1	-0.7	0.2	0.0	-0.1	0.4	0.9
OL VS. RS									
AGRICULTURE	-19.0	-21.4	-2.8	1.6	0.4	-0.8	-0.8	0.0	-2.4
FOOD INDUSTRY	-16.4	-17.0	-1.0	1.6	0.2	-1.1	-1.1	0.8	-0.6

Source: authors' own calculation

TABLE 46
Change (%) in consumer prices compared with the RS (2020-2030)



scenario) imposes little cost on agrifood sectors. Indeed, even with a 50% cut in multilateral applied tariffs (OL scenario), the fall in EU production is surprisingly muted, between 1.6% (agriculture) and 1.8% (food).

In terms of the EU's biofuel policies, as expected, the elimination of the policy in the IL scenario reduces agricultural output (-1.2%), whilst in the OL scenario, the raising of the blending mandate has the opposite effect (1.2%). Notwithstanding, from a food security perspective, these changes are entirely attributed to changes in biofuel feedstock production capacity rather than for direct consumption. Finally, further EU cuts in GHG emissions in the OL scenario have the most damaging impact on the EU's food security, explaining much of the relative fall in agrifood output in this scenario. In isolation the additional GHG cuts in the OL scenario result in output falls of approximately -4.5% and -1.6% in agriculture and food, respectively.

.Pg 107

Examining the evolution of the consumer price index for agriculture and food in the IL and OL scenarios compared with the RS (**Table 46**), the recorded net impacts are relatively small, reflecting an array of conflicting price directions arising from each of the policy drivers. In the IL scenario, agricultural and food consumer prices rise by less than 1% in the EU, whilst in the OL scenario, agricultural and food prices fall 2.4% and 0.6%, respectively. With the loss of the decoupled subsidy tied to the land factor in both IL and OL scenarios, the per unit cost (rent) of the land input rises which generates cost push increases in agriculture and, via price transmission, food prices. [42] This price inflationary effect is lessened in the OL scenario since some of the Pillar 1 support withdrawn from EU land is recapitalised as agri-environmental and least favoured area payments to land on Pillar 2.

In the IL scenario, the neighbourhood/regional trade shocks have a negligible price impact, whilst the multilateral trade deal, which is characteristic of the OL scenario, leads to gentle falls in agricultural and food prices resulting from cheaper access to imported produce and falling factor returns in contracting EU agricultural and food activities.

.Pg 100
.Pg 98, 85
Pg 77

In both the IL and OL scenarios, the consumer price effect from the GHG emissions shocks is below 1%. [43] At first sight, the similar relative change in consumer prices for both IL and OL scenarios is perhaps surprising since larger EU reductions in agricultural emissions (see **Table 43**) in the OL scenario would (ceteris paribus) drive up market prices through the direct impact of higher carbon taxes within agriculture's input and output markets. Further examination, however, reveals that mitigating factors are also at play in the OL scenario, as further GHG reductions also depress real land rents (**Table 41**) and agricultural wages (**Table 34**), as well reducing real incomes and growth (**Table 28**)

.Pg 98, 85
.Pg 77
.Pg 98, 77

The isolated impact of the biofuel mandate on consumer prices reflects both a 'price-effect' and 'real income' effect in the EU economy. Turning to the IL scenario, the removal of this policy leads to slight relative price falls in primary agriculture. The removal of mandates reduces competition for land such that real land rents and wage rates in the agriculture sector fall by -1.8% (**Table 41**) and -1.1% (**Table 33**), respectively. The biofuel policy impact on falling factor costs is stronger than the demand push effect arising from increases in real income due to the elimination of this policy (**Table 28**). [44] In the case of the OL scenario, the (negative) real-income effect appears to take precedence over the (positive) price effect, such that consumer prices fall for agriculture and food products under this policy shock. In other words, an ambitious increase in the mandate (especially for second generation) generates a significant rise in real land rents of 12.5% (**Table 41**), whilst the negative macro impact (**Table 28**) arising from supply bottlenecks to meet the mandate, leads to falling real incomes, wages and demand.

[42] In this model, perfect price transmission is assumed along the food supply chain.

[43] In the IL scenario, despite applying the same GHG emissions shocks as in the RS, this specific policy shock generates a small, but consistent price inflationary effect across all activities in the EU compared with the RS. Since the elimination of the biofuel mandate in this scenario is found to incrementally improve EU output and growth, under the same EU28 emissions constraint as the RS, the general level of relative EU prices is also driven upwards.

[44] In many non agrifood sectors, the elimination of the biofuel mandate is found to increase consumer prices, owing to the aforementioned real income effect.

5.3.2 Trade and self sufficiency

Measured at EU market prices, 2020 trade values (not shown) show that processed food has a larger weight with a greater emphasis on intra-EU trade links. On the other hand, the extra/intra-EU primary agricultural trade is more equally distributed. In 2030, the RS estimate for the EU trade deficit in agriculture and food is -€20,267 million and -€33,781 million, respectively (not shown). This statistic improves by €3,431 million (agriculture) and €10,009 million (food) in the IL scenario (not shown). The same comparison between the OL and RS shows that the agricultural trade balance improves €4,343 million, whilst that for processed food deteriorates further by -€7,337 million.

In self-sufficiency terms, the EU's estimated RS ratio in 2030 is 91% for food and 95% for agriculture (not shown). In the IL scenario, both statistics improve by 1.1 and 1.0 percentage points in agriculture and food, respectively. The corresponding results for the OL scenario show improvements of 1.3 percentage points in agriculture, and a deterioration of 1.0 percentage point for food.

These summary results are based on a complex interaction of different (and conflicting) drivers which are discussed below with the help of Table 47. Examining the role of the modelled CAP change shock in both IL and OL scenarios, this worsens the EU's agrifood trade balance as extra-EU imports rise and extra-EU exports fall. As expected, the magnitude of these effects is lessened in the OL scenario, since more land is maintained within agricultural production.

For the trade shocks, opening EU markets in both the IL and OL scenarios clearly generates greater trade dependence on, and market opportunities in, non-EU regions. In the IL scenario, the neighbourhood and TTIP trade policies increase agrifood extra-EU imports and exports, which, when taking into account the underlying value flows commented on above, leads to similar value flow increases in extra-EU exports and imports. The multilateral trade shock, which is characteristic of the OL scenario, generates some of the largest extra-EU trade shifts of all the policy shocks under consideration. There is a clear deterioration in the processed food trade balance as extra-EU import volumes increase by 29.3%; accompanied by a concomitant increase in extra-EU processed food export volumes of 15.3%. EU agriculture, on the other hand, appears to be relatively competitive on world markets, resulting in rises in extra-EU agricultural export volumes and falls in corresponding agricultural extra-EU import volumes.

Looking at the isolated impact of the biofuel policy shocks, from a food security perspective, one must be mindful that the changes in trade volumes are related to transactions of biofuel feedstock (i.e., biofuel crops, residues etc.), rather than food per se. Thus, the removal of the biofuel mandate in the IL scenario improves the agrifood trade balances (i.e., reduces imports and increases exports), but does not have clear implications for the EU's food security. Reduced usage of biofuel feedstock reduces intra-EU agrifood trade activity as well as the EU's dependence on extra-EU imports, whilst extra-EU agricultural export volumes rise as surplus capacity of biofuel feedstock is now dumped on world markets. In the OL scenario, when the biofuel

TABLE 47
Changes in intra- and extra-EU trade volumes (%) compared with the RS (2020-2030)

IL VS RS	RS	IL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
INTRA-EU TRADE									
AGRICULTURE	-1.8	-6.1	-0.1	-1.0	-1.5	-0.7	-1.0	0.0	-4.3
FOOD INDUSTRY	5.2	-2.1	-1.9	-1.3	-0.3	-1.4	-2.4	0.0	-7.3
EXTRA-EU IMPORTS									
AGRICULTURE	14.9	4.4	-6.8	-2.1	2.9	1.4	-5.4	-0.5	-10.4
FOOD INDUSTRY	54.5	38.6	-11.6	-3.8	0.8	5.7	-8.2	1.1	-16.0
EXTRA-EU EXPORTS									
AGRICULTURE	3.6	7.9	2.0	-0.7	-4.6	4.2	1.7	1.7	4.3
FOOD INDUSTRY	22.8	26.1	-1.3	-0.1	-0.5	5.0	0.3	0.0	3.3

OL VS RS	RS	OL	DECOMPOSITION BY SHOCKS VS RS (2020-2030) PROJECTIONS	FOSSIL FUEL PRICES	CAP	TRADE POLICY	BIOFUEL	GHG	DIFFERENCE IL VS RS
INTRA-EU TRADE									
AGRICULTURE	-1.8	-7.2	-0.1	1.1	-0.7	-1.0	1.0	-5.7	-5.4
FOOD INDUSTRY	5.2	-8.2	-2.2	-1.1	-0.1	-8.0	1.6	-3.6	-13.4
EXTRA-EU IMPORTS	14.9	3.1	-8.6	-7.4	1.4	-3.2	1.0	4.9	-11.8
AGRICULTURE	54.5	78.4	-11.1	-6.0	0.8	29.3	-3.8	14.8	23.9
FOOD INDUSTRY									
EXTRA-EU EXPORTS									
AGRICULTURE	3.6	14.6	2.3	5.9	-2.0	13.2	-2.2	-6.2	10.9
FOOD INDUSTRY	22.8	34.9	0.0	0.3	-0.3	15.3	2.5	-5.6	12.2

Source: authors' own calculation

mandate is increased, the primary agricultural trade deficit would increase. Resulting increases in agricultural activity (non-food related) in EU member states generates greater volumes of intra-EU trade, which are also diverted away from extra-EU exports. In addition, there are greater (non-food) agricultural imports from non-EU countries to help meet the mandate and reduced agricultural exports to non EU. As greater levels of processed food are also produced by the EU (given higher EU agricultural production), the rising mandate leads (ceteris paribus) to improved EU self-sufficiency in processed food products as extra-EU imports of food fall and extra-EU exports of food rise.

Finally, the influence of the GHG shocks in the OL scenario is one of a clear deterioration in relative trade competitiveness for the EU compared with the RS, with the result that relative trade volumes (and balances) deteriorate further. Thus, with the EU's economic slowdown, intra-EU trade and extra-EU exports fall relative to the reference scenario, whilst there is greater dependence on non-EU sourced imports. In the IL scenario, the GHG shocks remain unchanged from the reference scenario, although **Table 47** still shows some divergence with .Pg 111 the reference scenario. This is largely explained by the relatively improved economic situation in the IL scenario compared with the RS resulting from the abolition of the mandate. Although the emissions restriction for the EU28 remains unchanged, the 'optimum' distribution of emissions reductions by EU activities is now altered, resulting in some divergence in the part-worth of this policy shock compared with the reference scenario.

5.3.3 Economic development and nutrition

In Table 48, for the period 2013 to 2030, two measures of wellbeing closely related to food security are presented. On the one hand, food budget shares are calculated for all the major regions. With increases in real incomes per capita, food consumption patterns are revised to reflect Engel's Law. [45] Thus, between 2013 and 2030, **Table 48** reveals falling food expenditure shares in all regions, where in developing countries (e.g., MENA, SSA, China, India etc.), which are undergoing more rapid economic development, the fall in food budget shares is more pronounced.

Similarly, following Rutten et al (2013), the evolution of calorie intake per person per day between 2013 and 2030 is calculated. It should be noted that the calorie intake statistic does not net out the losses resulting from food waste in the home, or along the supply chain (from the farm gate to the point of sale). The general pattern is that calorie intake across all regions is increasing over the period, particularly in developing countries (SSA, India), although in most countries, calorie intake rises have already reached a plateau. Comparing across the three policy scenarios, differences in calorie intake are largely superficial, whilst in none of the three policy narratives, is calorie intake drastically affected.

In having access to an innovative Framework for calculating nutrient requirements for households, it will be possible in future work to more specifically target the impact of policy on food intake and consequently diet. Greater attention must be targeted at generating calorie results which better reflect the (expected) reality, especially in rapidly developing economies. This requires further trial and error experiments to better gauge the mechanism of changes in purchasing power parity per capita on household purchasing patterns, and consequently on household budget shares and nutrient uptake. Ultimately, it could be possible to analyse how targeted changes in nutrition and diet feedback to the wider macroeconomy.

[45] Engel observed that with rising real incomes, the share spent on food decreases, even as total food expenditure rises

TABLE 48
Household food budget shares (%) and calorie intake (per capita per day)

HOUSEHOLD BUDGET SHARE	2013 RS	2020 RS	2030 RS	2030 IL	2030 OL
EU28	13.0	11.5	10.01	9.99	10.18
USA	6.1	5.0	4.2	4.3	4.1
MERCOSUR	13.0	10.8	8.2	8.2	8.2
CHINA	19.1	12.1	7.4	7.4	7.4
INDIA	34.7	33.8	27.6	27.6	26.9
JAPAN	10.2	9.0	7.6	7.6	7.6
MENA	17.9	15.7	12.2	12.2	12.1
SSA	39.3	38.4	36.4	36.2	36.3

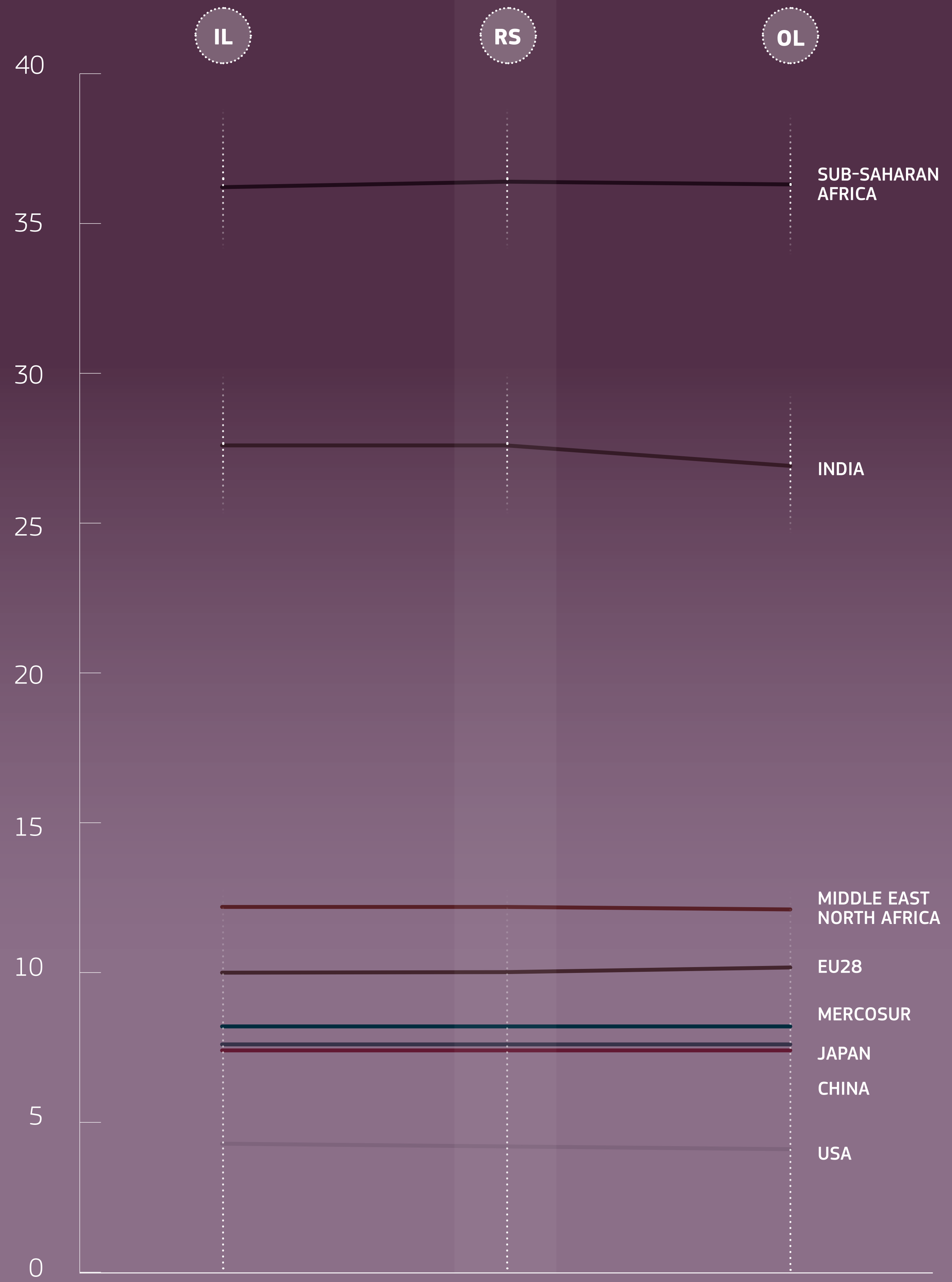
CALORIES	2013 RS	2020 RS	2030 RS	2030 IL	2030 OL
EU28	3441	3442	3494	3501	3516
USA	3903	3774	3719	3696	3774
MERCOSUR	3107	3108	3048	3059	3041
CHINA	3307	3323	3201	3213	3198
INDIA	2535	2742	2836	2843	2831
JAPAN	2824	2871	2861	2891	2951
MENA	3027	3037	3062	3074	3100
SSA	2337	2521	2661	2672	2668

Source: authors' own calculation

TABLE 48
HOUSEHOLD FOOD BUDGET SHARES (%) AND CALORIE INTAKE (PER CAPITA PER DAY)

HOUSEHOLD FOOD BUDGET SHARES (%)

	EU28	INDIA	CHINA
2013	13.0	34.7	19.1
2020	11.5	33.8	12.1
2030	10.01	27.6	7.4


IL
RS
OL
40
35
30
25
20
15
10
5
0
SUB-SAHARAN AFRICA
INDIA
MIDDLE EAST NORTH AFRICA
EU28
MERCOSUR
JAPAN
CHINA
USA

6 FINAL OBSERVATIONS, CAVEATS AND FUTURE DEVELOPMENTS

This study represents a first step into a very broad policy arena. It tackles complex questions relating to anticipated bio-based market trends, diverse uses of biomass and the issue of policy coherence. Although there are number of caveats, this should not detract from the important contribution that this study makes in providing a viable methodological framework for enumerating the opportunities and threats facing this collective of bioeconomy activities.


Passably cordial reception
to performance or work out of
respect in which the performer
author is held rather than on
count of the merits of the
itself. [Fr.]
cess marked by wild enthusia
[Fr.]
succĕ'ss
issue; attainment of object, or
wealth, fame, or position; thing
person that succeeds or is succe
ful; issue of undertaking (now
succĕ'ssfully adv.
succĕ'ssion (-ks-)

Final observations, caveats and future developments

The underlying message of the analysis is that the bioeconomy is set to face considerable challenges in the years ahead. In the EU, the importance of the bio-based sectors is expected to dwindle somewhat, both as a motor of jobs and growth. The factors underlying this result are mainly 'structural'. For example, the assumption of inelastic land supply in the EU supports the neoclassical (Heckscher-Ohlin) argument that bio-based land using sectors face a trade disadvantage compared with more land abundant non-EU regions (i.e., Mercosur). In relation to this first point, the 'reference scenario' hypotheses of sustained slower rates of land- and macroeconomic productivity in the EU, vis-à-vis other non EU countries, is clearly disadvantageous to EU bio-based sectors. Finally, in the 2020-2030 period, the study also assumes that EU activities, along with the USA and (to a lesser extent) Japan, shoulder a greater burden in reducing GHG emissions, relative to other countries, which the results show, clearly imposes a cost in terms of lost EU output. Indeed, it should be recognised that the fight against climate change is a global issue which requires a global solution. As a result, a more symmetric balance of responsibilities by all governments to affront this pressing concern, would also pay dividends by not unfairly penalising the economic performance of those countries which choose to show greater ambition in combating this problem.

In the context of the above, it is entirely conceivable that higher relative land productivity projections, or at least an endogenous treatment of land productivity linked to targeted EU investments in bio-technology innovation, would produce a recognisably more optimistic outlook for the EU bioeconomy. On this point, to realise desired productivity growth, secure and responsible biomass usage, climate action etc., there is a clear need for significant and targeted investments in bio-technology initiatives in the coming years, a view shared by the EU's strategy paper (European Commission, 2012). Indeed, considerable EU research and innovation funding over the period 2014-2020 is to be spearheaded by the 'Horizon 2020' initiative, whilst additional funding under the EU's Regional Policy, the State Energy Technology (SET) plan for energy and climate policy, and public/private Joint Technology Initiatives (JTIs) (Scarlat et al., 2014), certainly provide a strong basis for generating a range of innovative solutions to meet these societal challenges. In a similar manner, a less ambitious assumption on the evolution of EU GHG emissions reductions post-2020, and/or a (not unreasonable) assumption of relatively greater responsibility taken by non-EU regions in reducing their GHG emissions at a pace which matches the ambition of the EU, would undoubtedly generate a more positive outlook for EU bio-based (and non-bio-based) activity.

In addition, the study also shows that the promotion of non-market rural development goals under the auspices of the Pillar 2 of the CAP helps to restrain the (small) agricultural output falls; softens agricultural employment losses and wage reductions; and reduces land abandonment. Clearly this policy has the desired effect of balancing non-tangible sustainability goals with more pragmatic economic indicators.

Elsewhere, it is also expected that commodity prices, both within the EU and globally, will continue to fall in nominal terms. Moreover, as an example of a targeted investment in bio-based activity, the biofuel mandate succeeds in lowering (blended) petroleum prices, whilst also having a positive direct impact on bioenergy industries (1st and 2nd generation) and positive indirect impact on bioeconomy supply sectors (i.e., plantations, residues from agriculture and forestry, pellets), in terms of output and employment generation. On the other hand, there a 'bioeconomy supply bottleneck' cost from imposing such a policy. In this study, this efficiency cost is illustrated by the relative macroeconomic benefit (loss) associated with the removal (increasing) of the blending mandate in the inward-looking (outward-looking) scenario. This result appears to endorse more recent policy thinking which seeks to abandon direct blending mandates, in favour of linking biofuel usage with other goals relating to GHG emissions reductions.

At the current time, this study represents a 'state-of-the art' endeavour both in terms of the modelling and data developments in the field of CGE. Notwithstanding, there are still areas within which the study can still be improved. In this research, the base data is benchmarked to the year 2007, corresponding with the penultimate version (8) of the GTAP database. The necessary man hours required to separate new bio-based activities (i.e., bioenergy, biochemicals etc.) from existing GTAP parent industries and the uncertainty of the launch date of the next version of the GTAP database, precluded the possibility of employing the most recent incarnation (version 9 - 2011 benchmark year) of the GTAP data for this study. Notwithstanding, in the interests of further improving the precision of the study from a data perspective, future 'prospective studies' for bio-based sectors will look to employ a bio-based compatible version of GTAP 9 (2011 benchmark) data. Indeed, the data could also 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" (so-called blue growth industries).

A further point is in reference to the inclusion of the GHG module in MAGNET. Whilst the current representation is 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.

Given the increasing importance of climate policies in the EU, a more detailed modelling of these policies (e.g. inclusion of ETS and non-ETS sectors, auctioning in the power sector, RES target) would improve the quality of the current analysis.

An additional aspect to keep in mind is the treatment of technological adaptation across different economic activities. In the case of agriculture, for example, it is foreseeable that given the right incentives, farmers may invest in technological improvements (i.e., better feeds; more resistant strains of seeds; different farm management practices etc.) to better meet the challenge of climate change and environmental policy. Since there is no endogenous technological change induced by tightening emissions controls, then emissions reductions can only be met by exogenous technological assumptions on input substitution (within the production nests) or by reducing the scale of output. In short, 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.

A final area for future improvement would be the development of a more statistically rigorous approach for presenting the sensitivity analysis.[46]

To conclude, this study represents a first step into a very broad policy arena. It tackles complex questions relating to anticipated bio-based market trends, diverse uses of biomass and the issue of policy coherence. As intimated in the above paragraphs, there are number of caveats, although this should not detract from the important contribution that this study makes in providing a viable methodological framework for enumerating the opportunities and threats facing this collective of bio-based activities. It is expected that future endeavours of this type will build on the methodological advances made in the current study, whilst continued feedback from varied stakeholder groups and policy makers will ensure an enhanced degree of representative detail in the scenario designs which, in turn, should help to better inform the ongoing policy debate.

[46] Possible ways to approach this issue are a Monte Carlo type approach or the Gaussian Quadrature, the Stroud's quadrature and Liu's approach among others. To conduct a systematic sensitivity analysis with the Quadrature approach, variation or range in the shocks; an assumption of the distribution in the exogenous variables and whether or not the shocks vary independently or in unison should be provided. For each variable, the sensitivity analysis presents an estimate of the true mean and the standard deviation (degree of variability) of the results.

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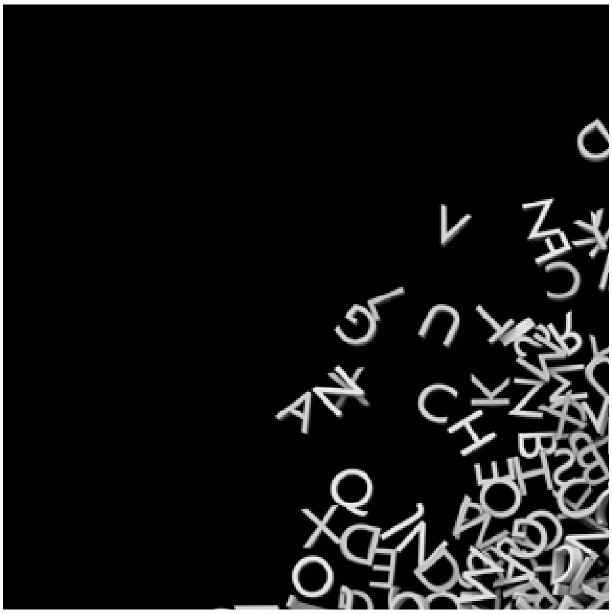
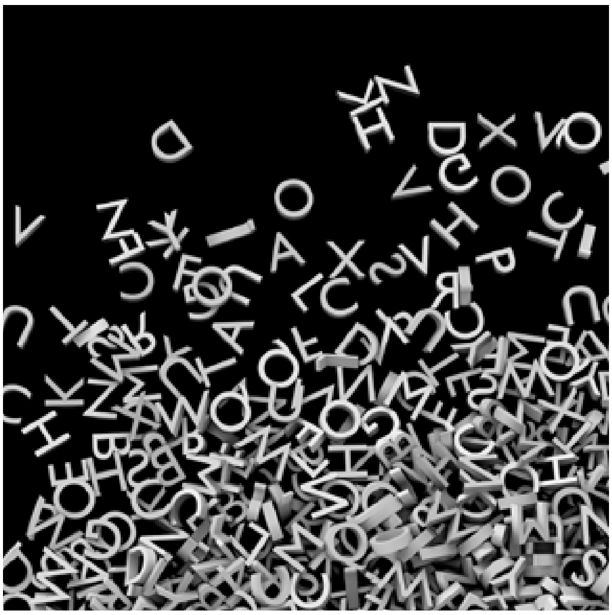
LIST OF ABBREVIATIONS AND DEFINITIONS

AgMIP	Agricultural Model Intercomparison and Improvement Project
BaU	Business as Usual
BTU	British Thermal Units
CAP	Common Agricultural Policy
CATS	Clearance of Accounts Audit Trail System
CET	Common External Tariff
COP21	United Nations Framework Convention on Climate Change
CGE	Computable General Equilibrium
DDGS	Dried Distillers Grains with Soluble
DG AGRI	Directorate-General Agriculture and Rural Development
EC	European Commission
ETS	Emissions Trading System
EU	European Union
EV	Equivalent Variation
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTAP	Global Trade Analysis Project
IL	Inward-Looking policy narrative
iMAP	integrated Modelling Platform for Agro-economic Commodity and Policy Analysis
IPCC	Intergovernmental Panel on Climate Change
LFA	Least Favoured Areas



MAGNET	Modular Applied GeNeral Equilibrium Tool
MENA	Middle East and North Africa
MERCOSUR	MERcado COmún del SUR
MFF	Multiannual Financial Framework
NTM	Non-tariff measure
OECD	Organisation for Economic Co-operation and Development
OL	Outward-Looking policy narrative
PCD	Policy Coherence for Development
PE	Partial Equilibrium Model
RCA	Revealed Comparative Advantage
ROW	Rest of the Word
RS	Reference Scenario
SDGs	Sustainable Development Goals
SFP	Single Farm Payments
SPS	Single Payment Scheme
SRES	Special Report on Emissions Scenarios
SSA	Sub-Saharan African
SSP	Shared Socioeconomic Pathway
TTIP	Transatlantic Trade and Investment Pact
UK	United Kingdom of Great Britain and Northern Ireland
USA	United States of America
VOLANTE	Visions of Land Use Transitions in Europe



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