Bio-based and Applied Economics 3(1): 83-91, 2014
DOI: 10.13128/BAE-14189

Observing and analysing the Bioeconomy in the EU – Adapting data and tools to new questions and challenges

Robert M'Barek*, George Philippidis, Cornelia Suta, Cristina Vinyes, Arnaldo Caivano, Emanuele Ferrari, Tevecia Ronzon, Ana Sanjuan Lopez, Fabien Santini

European Commission, Joint Research Centre (JRC), Institute for Prospective and Technological Studies (IPTS)

Abstract. The concept of 'bioeconomy' is receiving increased attention in policy and business circles. The European Commission (EC) has initiated the Bioeconomy Strategy which is a signal of intent that the EU seeks to meet the challenge of reconciling responsible-resource usage respecting sustainability criteria, with wealth-generation. To this aim, the EC's Joint Research Centre (JRC) has been entrusted to implement a Bioeconomy Information Systems Observatory within which the objective is to develop an ongoing coherent picture of the activities of this sector, whilst developing forward-looking tools of analysis to help respond to the aforementioned challenge. This paper provides a discussion on the research activities which are currently under development at the JRC. Whilst the scale of ambition of the Bioeconomy Observatory is significant, it is recognised that much of the research conducted so-far remains work-in-progress and is therefore only a starting point to fully capturing the nuances of this diverse and complex sector.

Keywords. Bioeconomy, European Union, Social Accounting Matrix, CGE, databases.

JEL Codes. Q1, Q2

1. Introduction

As a reflection of the importance of the 'bioeconomy' in European Union (EU) policy circles, in late 2012 the European Commissioner for Research and Innovation led an initiative known as the 'Bioeconomy Strategy', co-signed by the Commissioners for Agriculture and Rural Development, Environment, Maritime Affairs, and Industry and Entrepreneurship. Within this strategy, the EC defines the bioeconomy as, "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). Indeed, as a potentially important source of sustainable growth within the EU, the European Commission (EC) definition of 'bioeconomy' encompasses all kinds of biomass use whilst respecting three sustainability goals (economic, social, and environmental).

* Corresponding author: Robert.M'barek@ec.europa.eu.

ISSN 2280-6180 (print)
ISSN 2280-6172 (online)

www.fupress.com/bae

This holistic approach represents an opportunity for the EU to simultaneously reconcile responsible-resource usage and wealth-generation. On the other hand, existing European and global policies do not always provide a set of coherent objectives to be pursued at the same time. To better understand these conflicts of interest, one must first have a clear picture of the *status quo*.

According to the latest available official numbers for 2009, the bioeconomy in the EU represents a market estimated to be worth over EUR 2 trillion, providing 20 million jobs and accounting for 9% of the total employment (EC, 2012, p. 5). A more recent study (Carus, 2012a) estimates a turnover of EUR 2.8 trillion and approximately 29 million jobs for the year 2012. Nevertheless, both sources only provide broad estimates which are highly uncertain.

The Bioeconomy Strategy aims at focusing the EU's common efforts in the *right direction* to "help Europe to live within its limits. The sustainable production and exploitation of biological resources will allow the production of more from less, including from waste. The Bioeconomy will also contribute to limiting the negative impacts on the environment, reduce the heavy dependency on fossil resources, mitigate climate change and move Europe towards a post-petroleum society" (EC, 2014a). Yet, the definition of *right direction* is open to interpretation.

Accordingly, under the auspices of the Bioeconomy Strategy, a European Bioeconomy Panel has been set up to support interactions between different policy areas, sectors and stakeholders, in order to get a global overview of the different components and dimensions of the bioeconomy. The Bioeconomy Panel brings together, in one group, people with different perspectives and areas of expertise (EC, 2014b). In addition, an Expert Group for Bio-based Products has been created to assist the Commission in the preparation of legislation or in policy definition in particular in the framework of the reviewed industrial policy (Bio-based News, 2014). Furthermore, the EU Research and Innovation programme from 2014 to 2020, known as Horizon 2020, also includes research relevant to this sector (EC, 2014c). In addition to the EU strategy, several EU Member States have also designed their own national bioeconomy strategies, which are linked in particular through the Standing Committee for Agricultural Research (SCAR) to the European Commission.

On a separate front, the Bioeconomy action plan also foresees the establishment of a Bioeconomy Information Systems Observatory "to regularly assess the progress and impact of the bioeconomy and develop forward-looking and modelling tools." (EC, 2014d) The European Commission's Joint Research Centre (JRC), entrusted to implement the Bioeconomy Observatory, has proposed three main pillars which aim to: i) monitor investments in research, innovation and skills; ii) reinforce policy interaction and stakeholder engagement; and iii) enhance the knowledge of markets and competitiveness. In this short paper, the focus is on the last of these pillars, which aims at the description, quantification and analysis of the development of sectors in the bioeconomy from a socio-economic point of view. More specifically, this paper provides some insights into ongoing research activities within Bioeconomy Observatory of the JRC related to data and economic assessment tools implemented in-house under the auspices of the integrated Agro-economic Modelling Platform (iMAP) (M'barek *et al.*, 2012).

The paper is therefore organized as follows. Section 2 describes the JRC state-of-the-art data storing, comparing and visualisation tool for agriculture, markets and models, known as DataM. Section 3 deals with the description of bio-based sectors in each of the EU Member States (MS), based on the application of a detailed set of Social Accounting Matrices (SAM). Section 4 introduces a global simulation model for forward-looking scenario analysis. Section 5 concludes.

2. Databases and Visualisation of the BioEconomy

Since 2010, the JRC's in-house data management tool, known as DataM, has been employed to streamline data related tasks when researching agricultural markets. More specifically, it has been used as a source for economic modelling purposes, an easy to use data validation tool when cross checking between different databases, and as a way of analysing results. Using one interface only, users can rapidly access the main agricultural and trade databases (as provided by Eurostat, FAOSTAT, FAPRI, USDA, OECD and others) as well as the in-house model databases. The tool therefore addresses different needs, ranging from data collection and data checks to advanced reporting with the possibility to export data. The overall accessibility to DataM is extended through a web-based version, which was inaugurated in January 2014[2]. More information about this tool can be found in Hélaine *et al.* (2013).

The lack of data for measuring bioeconomy is one of the main challenges of the Bioeconomy Observatory. Currently, relevant indicators can be found in varied databases from different providers. DataM's contribution consists of providing access to different existing datasets collected both from publicly available sources, such as Eurostat and FAO, and non-public and/or *ad-hoc* data and that can be used by researchers, policy makers and general public to monitor bioeconomy figures in Europe.

To some extent, DataM already includes data relevant to certain areas of the bioeconomy, (e.g., agriculture, food, energy). For example currently available data for agriculture refers to production, land area, prices, agricultural trade, population and employment. Moreover, crops are more than just a source of food and feed (animal or human consumption), but also a main provider of biomass. As one of the data sources already available in DataM, the FAO Food Balance Sheet database provides, among others, valuable information for the bioeconomy as it also contains non-feed and non-food uses of crops.

In the future, the aim is to incorporate a comprehensive picture in relation to the other main sectors providing biomass: forestry, fisheries and aquaculture, industries other than food, biotechnology-based or not, and waste sectors. Since the objective of the Bioeconomy Observatory is to measure bioeconomic activity in the European Union, the main public data provider used for this purpose will be Eurostat.

Biomass is an important product of the bioeconomy which, until recently, has only received limited attention from statistical data providers. Very few databases include comprehensive data on biomass supply (such as production, market value); among those, two could be mentioned: Eurostat Material Flow Accounts and Seri Global Material Flow Database. To partly fill in the gap with respect to agriculture, the JRC in collaboration with the NOVA Institute is working on a database with estimates of biomass supply (fresh matter and dry matter). Using coefficients found in the literature, biomass dry mat-

[2] Accessible at http://www.datamweb.com/

ter is extracted from harvested agricultural biomass (fresh matter). In addition, thanks to the use of recovery coefficients, this dataset responds to the need of measuring used and unused crop biomass at the EU level. Unused biomass can then be used as an indicator of the scope of biomass available for recycling or fertilising activities. Further work will be needed for other sources of biomass.

There are also significant data gaps regarding the total biomass flows (use of biomass supplied), in particular concerning trade aspects, different uses between food, feed, fuel and other industrial purposes, and waste. The Bioeconomy Observatory will seek to combine information from various sources and datasets (such as, for example, industrial production and structural business statistics) to portray as comprehensive a picture as possible of the EU biomass balance sheet.

3. Profiling the BioEconomy using SAM Multipliers

In the context of different projects, the AGRILIFE unit at JRC developed 'Social Accounting Matrices for EU27 with a Disaggregated Agricultural Sector' (AgroSAM) (Mueller *et al.*, 2009) for each of the Member States. A description of the database building process and an example of its use in the examination of the bioeconomy for Spain can be found in Cardenete *et al.* (2012). In their paper, the authors employ multiplier analysis to examine the economic structure and relative influence of bio-based sectors relative to the rest of the economy. Following this line of research, traditional multiplier analysis is also employed as a vehicle to better understand the role of the bioeconomy across all EU27 Member States.

Forward linkage (FL) and Backward linkage (BL) are relative measures of supplier-buyer relationships within the economy under conditions of Leontief technologies. More specifically, the FL measures the relative importance of sector X as a supplier to the remaining industries in the economy whereas the BL measures sector X's relative importance as a demander of goods from remaining sectors. Thus, if sector X has a BL or FL greater than 1, then 1€ of intermediate input (BL) or output change (FL) in that sector generates an above-average level (i.e., greater than €1) of wealth measured against the remaining sectors. Those sectors which encompass FL and BL greater than 1 are identified as key or strategically important sectors.

As an initial step, it was deemed necessary to improve the relevance of the study by updating the AgroSAM tables for all of the EU27 members from the year 2000 to 2007.[3] The choice of update year is motivated by the availability of Eurostat Supply and Use Tables (SUT) for almost all of the EU27 regions. Thus, the non-agrofood accounts in the updated AgroSAM (i.e., industry costs, commodity supplies, exports, imports, final demands, investment demands, margins and net taxes) are taken directly from EU27 SUT tables. The agri-food sector accounts are updated to 2007 subject to additional secondary data targets from Eurostat (2013), whilst a further set of macroeconomic aggregate demand targets for each EU27 Member State (Eurostat, 2013) are also enforced subject to SAM balancing restrictions.

[3] Given the data intensive nature of input-output tables, there is typically a time-lag in their construction. This problem is further exacerbated when one is attempting to find a consistent year across 27 EU Member State.

As noted above, the desired application for these data is the calculation of multipliers for 45 designated bio-based sectors.[4] To aid the process of comparison and profiling of the bioeconomic sectors across Member States, a series of statistical tests are envisaged. Thus, employing a hierarchical cluster analysis, it is possible to identify regional clusters of EU members employing BL and FL variables as segmenting variables. In this way, the original 27 Member States are reduced to a smaller number of regional clusters, with a similar identifiable set of bio-based structures. To identify which bioeconomic sectors are structurally heterogeneous across clusters, one-way Anova tests can be implemented to focus on comparing the differences in the BL mean multiplier by sector and the FL mean multiplier by sector, across the clusters, whilst further identification of key sectors (FL and BL greater than 1) will pinpoint strategically significant sectors.

4. Simulating Macro-Economic Impacts of Biobased Technologies in the EU

To promote and monitor the development of the EU bioeconomy, the European Commission launched a complementary project to the Bioeconomy Observatory, the Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy project (SAT-BBE[5]). The SAT-BBE project aims at developing an analysis tool for monitoring the evolution of the biobased economy based on both quantitative and qualitative analytical models and tools.

There are already several models and tools that can be, and have been, used to evaluate certain aspects of the bioeconomy. For example, Plevin *et al.* (2013), Wicke *et al.* (2011), Edwards *et al.* (2010), Laborde (2011) and Kim et al (2011) analyse the impacts of first-generation biofuels on indirect land use change (ILUC). The first three aforementioned papers review existing models and highlight the modelling challenges when modelling ILUC. Laborde (2011) presents a detailed study using a customised computable general equilibrium (CGE) model linking trade liberalization, ILUC, biofuels and greenhouse gas (GHG) emissions. Employing a statistical analysis, Kim *et al.* (2011) detect evidence for ILUC that might have been catalysed by United States biofuel production.

Other studies (Ciaian and Kancs, 2011; Rathmann *et al.*, 2010) focus more on food security and land use competition between food production and biofuels with the use of statistical, time-series analytical mechanisms. While Timilsina *et al.*, (2011) employ a CGE for the same purpose, linking oil price, biofuel and food supply. Lastly, Tyner (2010) and Banse *et al.* (2008) have focused on the link between biofuel policies and global agricultural markets, the former with descriptive analytical tools and the latter with the use of a customised CGE model.

In the context of the Bioeconomy Observatory, a collaboration involving the JRC is currently underway which employs a customized recursive dynamic global CGE model

[4] Only those sectors where a clear bioeconomic input is identifiable are chosen (based on an examination of the intermediate input structure in the supply and use tables of the EU27. Other (aggregate) sectors such as chemicals, textiles etc., where a bioeconomic sector is present, were discarded owing to a large non bioeconomic component in the output of the sector, whilst a lack of information was available to disaggregate the bioeconomic from the non-bioeconomic component across all 27 EU members.

[5] http://www3.lei.wur.nl/satbbe/project.aspx.

known as the MAGNET model (Modular Applied GeNeral Equilibrium Tool)[6]. This model has already been applied to analyse the behaviour of the bio-based sectors and their inter-linkages with the rest of the economy (Van Meijl *et al.* 2012). One specific aim of the current study is to understand the role of second generation biofuel technologies capturing both the direct and indirect economic impacts of this bio-based sector.

From a data perspective, MAGNET principally relies on the well-known GTAP database which describes bilateral trade patterns, production, consumption and intermediate use of commodities and services. The current release of the GTAP database (Narayanan *et al.*, 2012) includes dual reference years (2004 and 2007) as well as coverage of 129 regions and 57 GTAP commodities. The input-output tables of several countries, especially OECD members, were adjusted in the GTAP 8 version, to match 2004 and 2007 agricultural production statistics by sector. These are particularly important adjustments for the bioeconomy, given the large percentage that agricultural products contribute to the final costs of bio-energy products. Within the SAT-BBE project, approximately 30 of the 57 sectors are classified as bio-based or potentially bioeconomy sectors, while some sectors include activities that are partially bio-based, such as food processing, wood and paper industries.

In terms of modelling, MAGNET builds on the standard GTAP CGE template by including non-standard modules that can be activated depending on the relevance of the policy question at hand. Thus, additional modules are activated to incorporate endogenous land supply and land transformation between sectors, whilst a specific module encompassing the activities of first generation biofuels and its interaction with (*inter alia*) agricultural sectors, is also included. In addition, MAGNET characterises fertilizer as a separate activity, considering the impact of this sector on crop yields and thereby on land use change. As noted above, the JRC will be looking to further extend the work to analyse the potential role of second generation biofuels, biochemicals and/or bio-electricity. The supply of biomass from woody or grassy crops and from residues and waste are not considered yet, but subject to data constraints, are important possible candidates for further research.

5. Conclusions

Before starting any analysis related to bioeconomy and partially incoherent objectives this concept brings about, a clear picture of available data and methodologies is needed. To this end, the European Commission established a Bioeconomy Observatory. Within this framework, the JRC is extending its web-based data management tool (DataM) to provide access to different datasets that can be used by researchers, policy makers and the general public to monitor in particular the primary sectors of the bioeconomy in Europe.

An analytical and economic way to better understand the role of the bioeconomy across all EU27 (28) Member States is performed through multiplier analysis. Updating and employing the 'Social Accounting Matrices for EU27 with a Disaggregated Agricultural Sector' (AgroSAM), developed at JRC, regional clusters of EU members, different bioeconomic structures and strategically significant sectors can be identified. Indicating significant and key sectors is already an important evidence for potential investments to

[6] http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/lei/Research-Areas/International-policy.htm.

foster growth and/or create jobs. However, constituting new markets, and at least parts of the bioeconomy are novel markets, as well as incentivizing investments, need a stable and long-term policy framework. Capturing the influence of policies and other drivers in a coherent framework can be achieved with the so-called general equilibrium models.

Within the Bioeconomy Observatory and in collaboration with other research institutions, the MAGNET model (Modular Applied GeNeral Equilibrium Tool) is used to analyse the behaviour of the bio-based sectors and their inter-linkages with the rest of the economy and Europe's trade relationship with third countries. Providing a consistent forward-looking economic framework, for instance the potential role of second generation biofuels, biochemicals and/or bio-electricity under specific macro-economic and policy assumptions, is quantified.

As an approach to steer biomass to its most beneficial uses for the economy, society, and the environment, the "cascading principle" (EP, 2013; p. 6) could become the guiding paradigm. As defined by the German federal Environment Agency, this framework provides a, "...strategy for using raw materials or the products made from them in chronologically sequential steps as long, often and efficiently as possible for materials and only to recover energy from them at the end of the product life cycle. It is based on the use of so-called 'cascades of use' that flow from higher levels of the value chain down to lower levels, increasing the productivity of the raw material" (Carus, 2012b, p. 2).

This definition places the use of biomass for energy generation at the end of the cascade, which at present is not the case, and therefore would not provide a level playing field for all actors (EC 2011) and equal access to – sustainable - biomass. Beyond these criteria, it is ultimately up to the society (and policy makers) to decide on the use of biomass. Choices are to be made.

To analyse the cascading use, a particular challenge from a modelling perspective is to identify and disaggregate those bioeconomic components of existing industry classifications to form new subsectors. In this way, a more detailed quantitative approximation of the importance of individual bioeconomy sectors on upstream suppliers and downstream markets is plausible, which more closely captures the concept of the cascading use.

Acknowledgment:

The project benefited from support granted by the European Union's Seventh Framework programme under Grant Agreement No 341300 (Bioeconomy Information Systems Observatory project).

Authors acknowledge valuable comments by Hans van Meijl, Alejandro Cardenete, Edward Smeets, Andrzej Tabeau, Maria del Carmen Delgado and Damien Plan. The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

References

Banse, M., v. Meijl H., Tabeau A. and Wojter G. (2008). "Will EU biofuel policies affect global agricultural markets?" *European Review of Agricultural Economics* 35(2): 117-141.

Bio-based News (2014). European Commission: Expert Group on Bio-Based Products established"; http://bio-based.eu/news/european-commission-expert-group-on-bio-based-products-established/ [2014, March 5].

Cardenete, M. A., Boulanger, P., Del Carmen Delgado, M., Ferrari, E. and M'Barek, R. (2014), Agri-Food and Bio-Based Analysis in the Spanish Economy Using a Key Sector Approach. *Review of Urban & Regional Development Studies*, forthcoming, doi: 10.1111/rurd.12022

Carus, M. (2012a). Structure of the Bio-based Economy, NOVA institute. Project presentation at Joint Research Centre.

Carus, M. (2012b). Bio-based Economy in the EU-27: A first quantitative assessment of biomass use in the EU industry; NOVA institute.

Ciaian, P. and Kancs D.A. (2011). Interdependencies in the energy–bioenergy–food price systems: A cointegration analysis. *Resource and Energy Economics* 33(1): 326-348.

Edwards, R., Mullighan D. and Marelli L. (2010). Indirect Land Use Change from increased biofuels demand - Comparison of models and results for marginal biofuels production from different feedstocks", JRC Scientific and Technical Reports (http://www.eac-quality.net/fileadmin/eac_quality/user_documents/3_pdf/Indirect_land_use_change_from_increased_biofuels_demand_-_Comparison_of_models.pdf).

Elbersen, B, Startisky, I, Hengeveld, G, Schelhaas, M-J, Naeff, H. and Böttcher, H (2012). Atlas of EU biomass potentials. Deliverable 3.3: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources. (http://www.biomassfutures.eu/work_packages/WP3%20Supply/D_3_3__Atlas_of_technical_and_economic_biomass_potential_FINAL_Feb_2012.pdf).

European Commission (2011). Bio-based economy in Europe: state of play and future potential - Part 2; Summary of the position papers received in response of the European Commission's Public on-line consultation), p. 6; http://ec.europa.eu/research/consultations/bioeconomy/bio-based-economy-for-europe-part2.pdf.

European Commission (2012). Innovating for Sustainable Growth: a bioeconomy for Europe" COM (2012)60; http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

European Commission (2014a). Bioeconomy Strategy; http://ec.europa.eu/research/bioeconomy/policy/strategy_en.htm [2014, March 5].

European Commission (2014b). Bioeconomy Panel; http://ec.europa.eu/research/bioeconomy/policy/panel_en.htm [2014, March 5].

European Commission (2014c). Horizon 2020; see Societal challenge 2, titled "Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the Bioeconomy"; http://ec.europa.eu/research/bioeconomy/h2020/index_en.htm [2014, March 5].

European Commission (2014d). Bioeconomy Information Systems Observatory; http://ec.europa.eu/research/bioeconomy/policy/observatory_en.htm [2014, March 5].

European Parliament (2013). REPORT on innovating for sustainable growth: a bioeconomy for Europe (2012/2295(INI)); http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+REPORT+A7-2013-0201+0+DOC+PDF+V0//EN

Hélaine S., Himics, M., M'barek, R., Caivano A. (2013). DataM - Data on Agriculture, Trade and Models; a tool for flexible management, extension and integration of (model) databases, JRC Scientific and Policy Reports (http://ftp.jrc.es/EURdoc/JRC81668.pdf).

Horridge, M. (2003). Sambal: a Gempack program to balance square SAms. Technical report, Center of Policy Studies, Monash University. (http://www.copsmodels.com/archivep/tpmh0048.zip).

Kim, S. and Dale B.E. (2011). Indirect land use change for biofuels: Testing predictions and improving analytical methodologies. *Biomass and Bioenergy* 35(7): 3235-3240.

Laborde, D. (2011). Assessing the Land Use Change Consequences of European Biofuel Policies - Final Report. Washington D.C., U.S.A., International Food Policy Research Institute (IFPRI).

M'barek, R., Britz W., Burrell A. and Delincé J. (2012). An integrated Modelling Platform for Agro-economic Commodity and Policy Analysis (iMAP) – a look back and the way forward, JRC Scientific and Policy Reports (http://ftp.jrc.es/EURdoc/JRC69667.pdf).

Mueller, M., Perez-Dominguez, I. and Gay, H. (2009). Construction of Social accounting Matrices for EU27 with a Disaggregated Agricultural Sectors (AgroSAM). JRC Scientific and Technical Reports (http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2679).

Narayanan G.B., Aguiar, A. and McDougall R. (Eds) (2012). Global Trade, Assistance, and Production: The GTAP 8 Data Base, Center for Global Trade Analysis, Purdue University". (https://www.gtap.agecon.purdue.edu/databases/v8/v8_doco.asp).

Plevin, R.J. and Kammen D.M. (2013). Indirect Land Use and Greenhouse Gas Impacts of Biofuels. Encyclopedia of Biodiversity (Second Edition). Waltham, Academic Press: 293-297.

Rathmann, R., Szklo A. and Schaeffer R. (2010). Land use competition for production of food and liquid biofuels: An analysis of the arguments in the current debate. *Renewable Energy* 35(1): 14-22.

Smeets, E., Vinyes, C., Tabeau, A. and Van Meijl, H., (Under review 2014). Evaluating the macro-economic impacts of biobased technologies in the EU. JRC Scientific and Policy Reports.

Timilsina, G.R., Mevel S. and Shrestha A. (2011). Oil price, biofuels and food supply. *Energy Policy* 39(12): 8098-8105.

Tyner, W.E. (2010). The integration of energy and agricultural markets. *Agricultural Economics* 41: 193-201.

Van Meijl, H., Smeets, E., Van Dijk, M., Powell J. and Tabeau, A. (2012). Macro-economic impact study for BioBased Malaysia. The Hague, The Netherlands, LEI Wageningen UR.

Vries, B de., Vuuren, D van., Elzen, M den. and Janssen, M. (2001). The targets Imange energy regional (TIMER) model. Technical Documentation. RIVM report 461502024, Bilthoven.

Wicke, B., Verweij, P. van Meijl, H. van Vuuren, D.P. and Faaij, A.P.C. (2011). Indirect land use change: review of existing models and strategies for mitigation. *Biofuels* 3(1): 87-100.