Towards a bio-based economy in ports : the case of the flemish-dutch delta

Towards a bio-based economy in ports: The case of the Flemish-Dutch Delta

Joost Hintjens[1], Thierry Vanelslander,[2] Martijn van der Horst,[3] Bart Kuipers,[4]

Abstract

The storage and distribution of hydrocarbons constitutes for many ports an important part of their activity. However, the use of fossil carbon will diminish during the next decades. This happens because of economic reasons (the supply is running out), ecological reasons (to diminish the impact of the greenhouse gasses), and technological reasons (new and more sustainable processing techniques have emerged). The shift from a fossil fuel based economy towards a bio-based economy has received a lot of attention since about 2010. From an academic perspective, the role of seaports and its chemical complexes in the bio-based economy is in an emerging stage and not clearly defined. This paper defines the relatively new role of ports in the bio-based economy and comes up with a set of indicators to measure the size and development of the bio-based economy on ports. The approach is founded on a literature review and interviews with key informed persons. Although the paper is conceptual in nature, it finds its application in the Flemish Dutch Delta – a port delta with one of the largest chemical clusters worldwide. The formation of clusters and their relation to the ports is analysed. It also describes different possible scenarios from a logistics viewpoint after the take-off of the BBE economy, which today is still in its infancy, and their effects on seaports.

Keywords : ports, industrial clusters, bio-based economy, Antwerp, Rotterdam

Article Classification R40, R41, R42, R58

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Authors' biographies

Joost Hintjens(°1962) got his master degree in Commercial Engineering at the University of Antwerp in 1986 and started a career in the industry while getting his Master in Management at the University of Ghent in 1993. He worked for several mid-sized European industrial companies with a focus on international marketing and logistics. He was general manager of companies in Belgium, Holland and Czech Republic for a French industrial group when he switched to teaching in 2002. First part-time at the Atheneum in Antwerp but from 2006 full-time as lecturer Logistics at the ArtesisPlantijn University College. He is currently chair of the course group Logistics at ArtesisPlantijn and researcher at the University of Antwerp where he is focusing on the role of ports in the supply chain. His interest goes mainly to the role of

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logistics at mid-sized companies and the relations with their clients and suppliers in controlling the supply chain. He started his PhD research at the end of 2012 with the co-operation between adjacent seaport authorities as subject.

Thierry Vanelslander (°1975) graduated as a doctor in Applied Economics at the University of Antwerp in 2005. He currently is tenure track assistant professor at the Department of Transport and Regional Economics. Until 2013, he was holder of the BNP Paribas Fortis chair on transport, logistics and ports. Until halfway 2009, he was director of the Research Centre on Freight and Passenger Transport, hosted by the Department of Transport and Regional Economics, to which he still is a promoter now. In his academic career, he took off as a researcher at the University of Antwerp for several research projects in the field of transport and regional economics. He is currently course co-ordinator for the courses Transport Economics and Maritime Technology. His research focuses on business economics in the port and maritime sector, and in land and air transport and logistics. His PhD dealt with co-operation and competition in sea-port container handling.

Martijn van der Horst (°1977) is a senior researcher and lecturer in Port Economics at Erasmus University Rotterdam. Martijn has a background in Logistics and Transport Management (BEng, 2000) and Economics (MSc, 2003). He worked for an international consultant company and taught logistics and transport economics at a school for higher professional education. Martijn is experienced in market-based research and policy advice, Bachelor and Master Education and scientific research. He participates in a wide range of research projects like sector studies, port development studies and studies related to port-related container transport. He combines his research with teaching port-related subjects at MSc and Bsc level.His main academic interest lies in coordination issues in hinterland transport chains from an institutional economic perspective. He has published a number of papers on this subject and is working on a related PhD-thesis.

Bart Kuipers (°1959) works at Erasmus Smart Port Rotterdam and RHV, a valorisation business of the Erasmus School of Economics. Bart Kuipers graduated as an economic geographer (1988) and received his PhD in economic geography in 1999, both at the State University of Groningen, The Netherlands. His PhD was devoted to the port-based chemical industry, in which different firms in the Port of Rotterdam were analysed in debt with respect to industrial restructuring, new logistics strategies and the demands these firms placed on the maritime and logistics industry. After a career of nearly ten years at the Ministry of Transport, where he worked as a policy adviser and as a research co-ordinator logistics & knowledge development, he worked for two years as a researcher at Delft University of Technology, faculty Technology, Policy and Management. In 2000-2008 he worked at TNO, the Netherlands organization for applied scientific research, as a consultant. Since 2008 he works for Erasmus University Rotterdam as a research manager port economics. His specialisations are logistical development studies, port development studies, port strategy and regional transformation processes. Next to a large number of research studies in the Netherlands—especially for the port of Rotterdam and the Dutch government—Bart Kuipers has performed port research projects for South Korea, the Netherlands Antilles, South Africa, India and the EU.

1. Introduction

From the middle of the last century, fossil fuels replaced in an ever increasing way renewable, natural sources as supplier of raw material for the industry and energy production and consumption. Before the generalised use of petroleum as a fuel and the manufacturing of synthetic materials out of it, most manufacturers used natural resources like flax, cotton, leather, wood, rubber, lactic acid, whale oil, etc.. all of which are by definition renewable. In recent years, it has been recognized that humanity uses the earth's natural resources in an unsustainable way, thus exhausting the environment and depleting the stock,of raw materials which will cause prices and external costs of fossil materials to increase. By being largely dependent on fossil fuels to drive our economy, major challenges lie at the heart of the sustainability problem (GEA, 2012). In the 21st century, more and more effort goes into finding alternatives for fossil fuels such as natural gas and oil. From the cradle-to-cradle concept, technologies and processes are being developed to use renewable, biological materials to replace finite, fossil sources as an input in energy or chemical production processes. Examples are found in the development of biodiesel (Pinto et al. 2005) and other biofuels (Börjesson and Mattiasson 2008). Vandermeulen et al. (2012) predict that 25% of the petrochemical production will have become bio-based by 2030. The increasing use of this type of bio-based activities mark an evolution that, in general, can be defined as a transition towards a bio-based economy (BBE). Also ports, traditionally places for cargo handling, storage and industrial activities, are moving towards a bio-based economy. The goal of this paper is improve the understanding of the transition towards a bio-based economy in ports, by defining its size and growth. The paper will focus on the BBE in the Flemish-Dutch port Delta (FDD). Nevertheless, the topic of BBE is currently studied all over the world; from post-industrial countries who want to reduce their dependence on fossil fuels (Pellerin and Taylor 2008; Jenkins 2008; Dornburg, Hermann, and Patel 2008) to developing countries who want to create value added with their raw materials (Forster-Carneiro et al. 2013; Pinto et al. 2005). The FDD includes the two largest port-industrial complexes of Europe, namely Antwerp and Rotterdam, but also several smaller ports like Flushing, Ghent, Moerdijk, Ostend, Terneuzen and Zeebruges. It is the ambition of the FDD to evolve into "an integrated chemical complex producing high value materials by using relatively clean energy sources and creating minimal environmental impact. Energy production will be sustainable and transnational. (...) Large flows of bio-based materials will arrive at the Delta and will be exported in the form of advanced bio-materials and semi-finished products produced locally as well as all over Europe" (Vanelslander et al. 2011).

Studying the bio-based economy in the context of ports is rather new. Literature on this port and transport segment is scarce. Since, especially in the bulk segment, trades in energy products make up for a large part of the throughput of many ports, it would seem worthwhile to study the effects of a transition towards bio-based products on the port throughput. There is sensibly more literature on the topic of 'green ports', of which performing as a sustainable production area is only one of many issues. Acciaro et al. (2014) highlight the often lacking relationship between port authorities' stated environmental goals, and the environmental projects and processes they actually manage. It turns out that objectives that relate to the regulatory and landlord function feature more frequently and score higher. At the same time, green actions related to its community manager function seem to be the more successful ones. That implies that the objectives strived for through concrete actions, lead primarily to positive but unplanned effects linked to other objectives. Some objectives indirectly could be linked to BBE, like e.g. 'include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet', or 'stimulate and facilitate port users in adopting green practices'. However, nowhere BBE or its sub-activities get explicitly mentioned. Another good framework on green ports and supply chain management is provided by Lam and Van de Voorde (2012). The general outcome of the research is that applying green port initiatives contributes to the port's economic well-being.

Moreover, it should be acknowledged that the BBE is a future-oriented concept that is often used in the stages of feasibility studies or pilot projects nowadays. Rotmans and Horsten (2012) stated that the bio-based economy is in its pre-development stage. The same position is taken by the Dutch Ministry of Economic Affairs, Agricultures and Innovation (2011). They conclude that the BBE has reached a "take-off phase". The fledging character makes it difficult but important at the same time to make a definition of the BBE, and a selection of indicators to show its size and growth. Therefore, this paper is explorative in its nature, with the goal of understanding the present and future importance of the evolution of the BBE in the FDD.

Given the explorative nature of the research, semi-structured expert interviews (thus making sure all necessary information was collected while leaving the experts room to elaborate in their specialities) were held with different actors in the BBE chain in the FDD, like suppliers, producers and users of bio-based materials, representatives of the port authorities, policy makers and academic scholars. The experts were selected based on their expertise and helicopter view on the one hand and on the role their organisation plays in the supply chain and more specifically the bio-based stream therein on the other hand. The covered chain starts with the producers of the resources represented by the farmers union (Boerenbond) and a waste collection company (Van Gansewinkel). Next in line are the transformers that turn these resources into materials (Rewin West Brabant, Dow Chemicals) and the researchers (Bio Base Europe) that develop the processes. In the value chain, the ports play a role in handling the resources and the materials (Zeeland Seaports and Port of Ghent); the last in line are the users of the materials (Essenscia and Biobase Delta) and the policy makers (province Zuid-Holland).

A list of the interviewees can be found in Annex 1. During the interviews, the following topics were discussed: definition of BBE, indicators and success and fail factors to illustrate the transition towards a BBE, selection of most important players in the BBE, and business opportunities. The second research step was a literature review in order to define the bio-based economy and to come up with a set of indicators to measure its size and growth. Thirdly, business data were collected for the selected indicators.

The paper is structured as follows. Based on the literature review and expert interviews, the bio-based economy is defined in section 2. Section 3 operationalizes the definition and indicators in the context of the FDD. In this section, the present size and growth of the BBE will be discussed for the FDD, like the number of companies, their evolution, the regional economy, and the formation of clusters and their location in relation to ports. In section 4, the expected evolution after the take-off stage and the impact on logistics and ports is given,. The final section summarizes and concludes.

2. Bio-based economy: definition

Within the European Union, including among others The Netherlands and Belgium, there is a clear trend towards an increased use of bio-products in the processes of energy and chemical production. As indicated in the introduction, the BBE is a new concept. This is also reflected in the few numbers of publications in academia or from policy makers before 2010. A bibliographic analysis from Vandermeulen et al.(2010) shows that the term bio-based economy was first used in scientific research in 1988. Furthermore, they conclude that hardly any literature can be found in the area of economics dealing with BBE. The scientific focus mainly lays on chemistry and biotechnology, agriculture, energy and fuels, and engineering.

The short time this concept has been in use has not yet allowed a firm definition to become established.

The OECD defines the bio-based economy as 'the sustainable production and conversion for food, health, fibre and industrial products, and energy'(Martinez-Fernandez et al. 2013). The European Commission (2012) refers to the bio-economy (BE) as 'the production of renewable biological resources and their conversion into food, feed, bio-based products and bio-energy" Like the OECD, the European Commission acknowledges that BBE or BE is based on sustainable production, but the OECD includes in their definition also the production of biomass. The Centre for Biobased Economy (CBBE 2013), a leading Dutch institution in the field, defines the bio-based economy as "an economy where green resources are used to sustainably produce non-food products, both end-products as well as inputs or additives". In a study on measuring the size of BBE in Flanders, Vandermeulen et al. (2011) define BBE in a broad sense, namely as "an economy for which all inputs come from renewable sources". Moreover, Vandermeulen et al. (2011) stress the importance of making a distinction between traditional and non-traditional use of biomass as an input in the definition of the bio-based economy. The non-traditional application of biomass does not incorporate the agri-food sector nor the feed production. This explains the difference between the above-mentioned definitions (BE vs. BBE). The definition of bio-economy (BE) does include food and feed, and bio-based economy (BBE) does not. Interesting in this respect is that an earlier definition of the European Union et al. (2009) excluded food, and a later publication (European Union 2012) included foodstuffs. Academics use definitions that are more convergent (Carrez, 2012 and Vandermeulen et al. 2011).

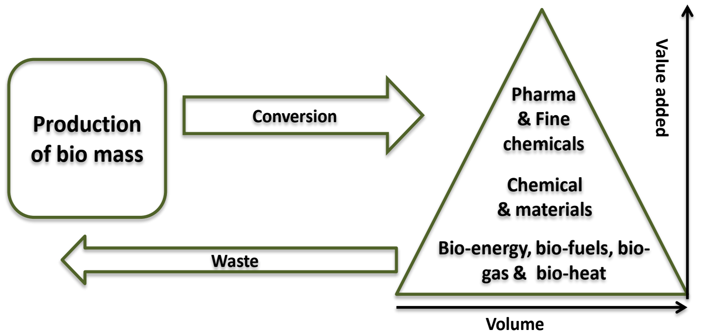
In this paper, the following definition is used: *Bio-based economy (BBE) is that part of the production economy that makes in an innovative way use of natural, renewable resources for material or energy production. Innovative means the replacement of fossil materials*.

This definition emphasizes the dynamic and evolutionary aspect of the BBE and the importance to focus on those sectors that have the highest growth potential. This is done by only including the non-traditional, inventive applications. This means that food-and-feed is excluded, but also bio-pharma, because both have been using bio-based resources since time immemorial.

In relation to this definition, two additional remarks can be made. First, it should be noted that it is not the source that defines BBE but the application. For example, maize can be feed but also feedstock for bio-fuel. When they are passing through the supply chain, this distinction might be transparent for the handler. Potatoes that are used to make fries fall outside the definition of BBE but the residual waste that might be used to make bio-plastics will be included.

Second, it should be realized that given the pre-development phase of the BBE, it is not a 'real' sector. It consists of multiple sectors. Many sources (Annevelink 2013; Carrez 2012; Vandermeulen et al. 2011) agree that the BBE can be presented by a 'value pyramid' (figure 1). The width of the pyramid indicates the volumes and the height from the bottom the added value of the bio-based products.

Figure 1. Stages and the value pyramid of the bio-based economy



Source : own composition, adapted from Biobasedeconomy.nl (2013)

The bottom of the pyramid consists of bio-energy: bio-heat, bio-gas, bio-electricity and bio-fuels. Next, with increasing added value, come the bio-chemicals like bio-plastic and the bio-materials. Some sources will top off the pyramid with bio-pharma (European Union et al. 2009). Other sources will use as a base the whole food and feed production (European Commission - Directorate-General for Research and Innovation 2012). Figure 1 also shows that three different stages can be distinguished in the bio-based production economy.

The first stage is the production of biomass, which consists of primary natural resources such as wood and algae. However, one can also use the waste streams of later stages in the production processes as an input, for instance in the case of animal fat or residues. The term "circular economy" is an important notion in the current bio-based trend. It is a larger concept than BBE. Also non-bio-based resources like glass or metals can be re-used to create a circular recycling process. From the interviews and literature review, it became clear that it becomes increasingly important to re-use waste and materials in order to shift some pressure away from the earth's natural resources. A shift from a linear to a circular economy by using secondary resources might eventually be necessary in order to maintain our current standards of living (Environmental Services Association 2013). The second stage entails the conversion of biomass, which can be done in various ways depending on the type of input and industry demand (e.g. fermentation). The final stage is the manufacturing process of different bio-based products as shown in the value pyramid in figure 1.

The next section focuses on the importance of BBE, as defined here, in the FDD.

3. The size and growth of the BBE in the FDD

Biomass is an important source for food and energy for humanity, but of the global annual production of 170 billion tonnes, only 3,5% (6 billion ton) is used : 62% is food and 33% are wood products that are used for energy (Devriendt et al. 2012). The part that goes to the BBE is still limited. 3% of the electricity of Flanders, 3,1% of transport fuels and 8% of the chemicals in Europe are based on biomass (Vandermeulen, Nolte, and Van Huylenbroeck 2010). The BBE is estimated at 0.46% of the Flemish GDP, but the segment is dynamic and growing fast (Carrez 2012). In The Netherlands, the situation is similar.

Bio-based electricity production is still modest but its market share is growing (Figures 2 and 3) (IEA 2014).

Figure 2. Belgian electricity generation by fuel

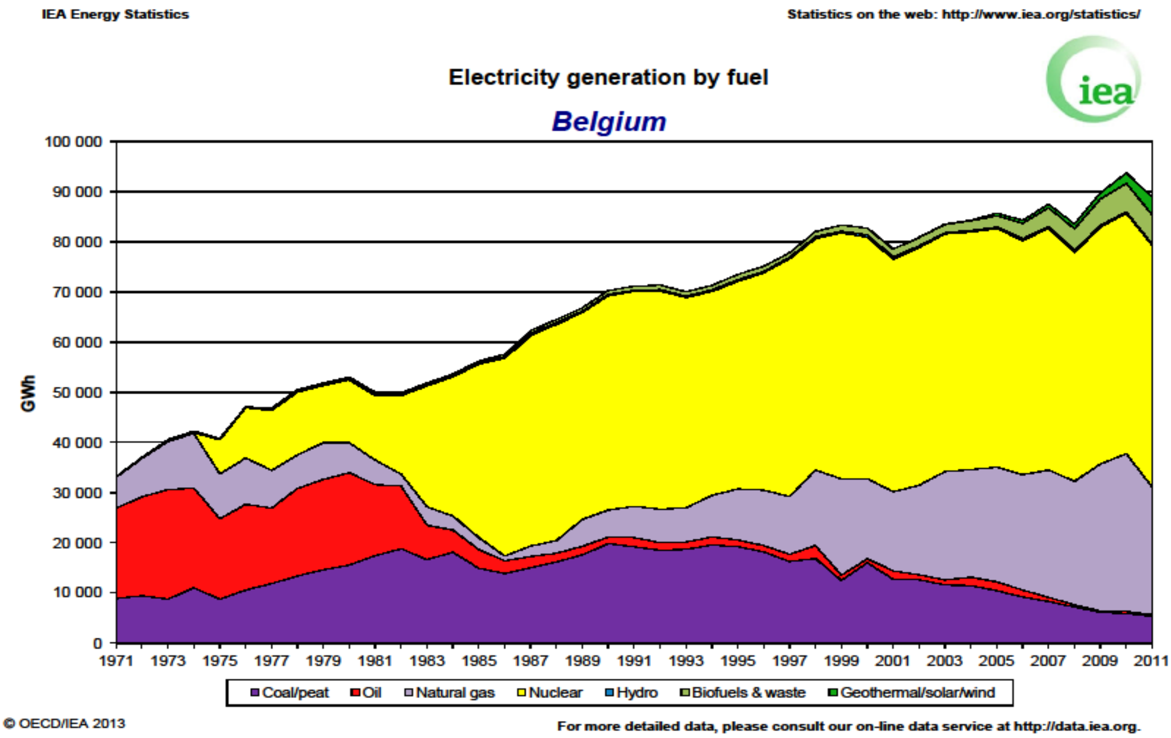
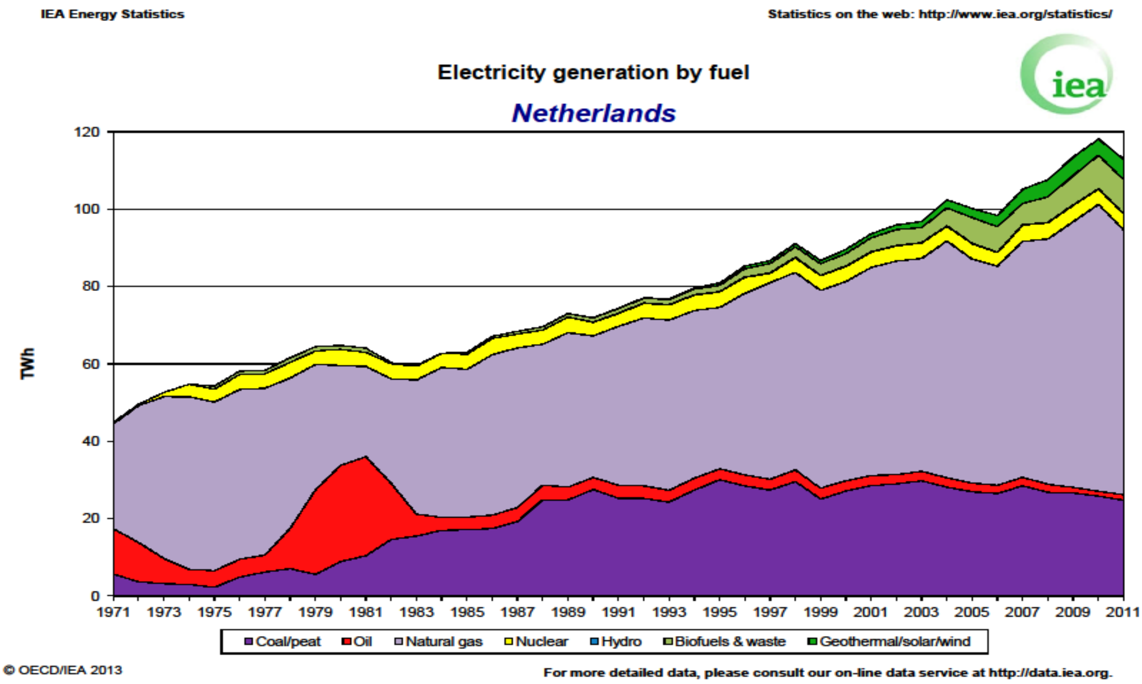


Figure 3. Dutch electricity generation by fuel



Number of firms in active in the Bio-Based Economy of the Flemish-Dutch Delta

Because the bio-based industry consists of parts of other industries (agriculture, chemical industry and energy) and given the fact that the BBE is in its pre-development phase, there are no statistical codes available within the national statistic bureaus. In order to identify the number of firms active in BBE in the FDD, a database was constructed. The main sources identifying these firms were the different websites of BBE initiatives or BBE institutions like Biobased Economy (2013), Biobased Delta (2013), Biobased Innovations (2013) and Cinbios (2013)[5]. The data sources altogether form a database of 91 companies, most likely including the majority of companies active in the bio-based economy in the Delta. A number of firms might not have been included because they were not listed in any of the mentioned sources. In addition, it should be noted that the term 'bio-based' is primarily a term that a company can give to itself. By subscribing to one of the earlier mentioned websites or institutions, it becomes public that a particular company is active in the bio-based economy.

Table 1. Number of firms in different stages of BBE

Stage	Typical activities	Number of firms	Share	Examples of firms
1 production of biomass	Production and storage of biomass	16	15%	NNRGY, Stora Enso, Sea-Invest
2 conversion	Conversion technology	15	14%	Clean Technologies, BioTorTech, C2Circle
3 production bio-based products	Bio-based products and bio-based energy	49	46%	Alco Biofuel, Cosun Biobased Products, Purac Biochem
Circular	Recycling, re-using materials	18	17%	Suiker Unie, Yara, LambWeston
Other	Consultancy, finance, institutions	9	8%	Bio Base Europe, Capricorn, Millvision

Source: Biobased economy (2013), Biobased Delta (2013), Cinbios (2013), Orbis (2013). Note: firms that are active in multiple stages of the bio-based economy are included several times. Therefore, the total count of firm's activities is 107 instead of 91.

Based on the defined three phases of the bio-based economy, the firms can also be grouped according to their main bio-based occupation, namely production of biomass, conversion and production of bio-based products. Some companies are active in all stages, which are called 'circular', and some companies deliver additional services like finance and advisory work.

[5] Biobasedeconomy.nl is an initiative of Agentschap NL, the Dutch agency for innovation and sustainability of the Ministry of Economic Affairs, Agriculture and Innovation. Biobased Delta is a joint coalition of businesses, local government and knowledge institutions in the south-west of the Netherlands (North Brabant and Zeeland). BioBased Innovations consists of a programme developed by several organisations in the south-west region of The Netherlands, stimulating innovative ideas in the bio-based sectors. For the Belgian provinces, the Cinbios membership list provided the data of a number of bio-based companies active in Flanders. Cinbios is an initiative of FlandersBio, Ghent Bio-Economy Valley and Essenscia, the Flemish organization for the life sciences and chemical industry. It should be noted that Cinbios is the Flemish database for so-called 'industrial biotechnology' or 'white biotech' companies. There are no differences between these terms and the notion of bio-based companies.

Table 1 shows the number of firms active in one or more stages of the bio-based economy. By far the largest group of firms (46%) is active in stage 3, the production of bio-based energy and materials. There are several possible explanations for this high share. First, with only a few different types of biomass (e.g. algae, wood pellets and waste), many different bio-based products can be made. Second, most value is created in stage 3 of the bio-based chain. With fine chemicals and pharmaceuticals topping the list, most added value probably lies in the production of bio-based products rather than biomass itself. Stages 1 and 2 and circular feature more or less the same amount of companies. Of the 91 firms active in BBE in the FDD and that were collected in the database as mentioned before, only a slight majority (47 firms) are so-called 100% bio-based firms (table 2). These firms produce only products or services with a bio-based character.

The other 44 firms are partly active in the bio-based activities beyond their traditional business. They are mainly 'greening' their traditional business.

Table 2. Distribution of firms by bio-based focus

Year 2011	# companies	Employment
100% bio-based	47	570
Partially bio-based	44	No reliable data
Total	91	

Source: Biobased economy (2013), Biobased Delta (2013), Cinbios (2013), Orbis (2013)

Employment in the BBE of the FDD

The employment at partially bio-based companies is difficult to estimate based on public data: a large part of the personnel is active in non-bio-based activities. The 100% bio-based companies are, on average, small with an average employment of 12 people. Table 3 shows that the number of people employed at 100% bio-based firms has increased in recent years. This indicates the growth of the sector. From 2005 onwards, the number of firms active in BBE grew. Another point that can be made is that some products have been increasingly popular among consumers or firms. Good examples are biodiesel/bio-ethanol, which can be used in cars, and bio-plastics instead of oil-based products. Although employment has grown in recent years, it remains small. Three comparisons can be made (table 3). First, compared to the direct employment in the ports of the FDD, which counts 214,035 FTE in 2007, the employment of 315 FTE in the FDD's BBE represents only 0.15%.

Table 3. Growth of employment in FDD, BBE and related industries

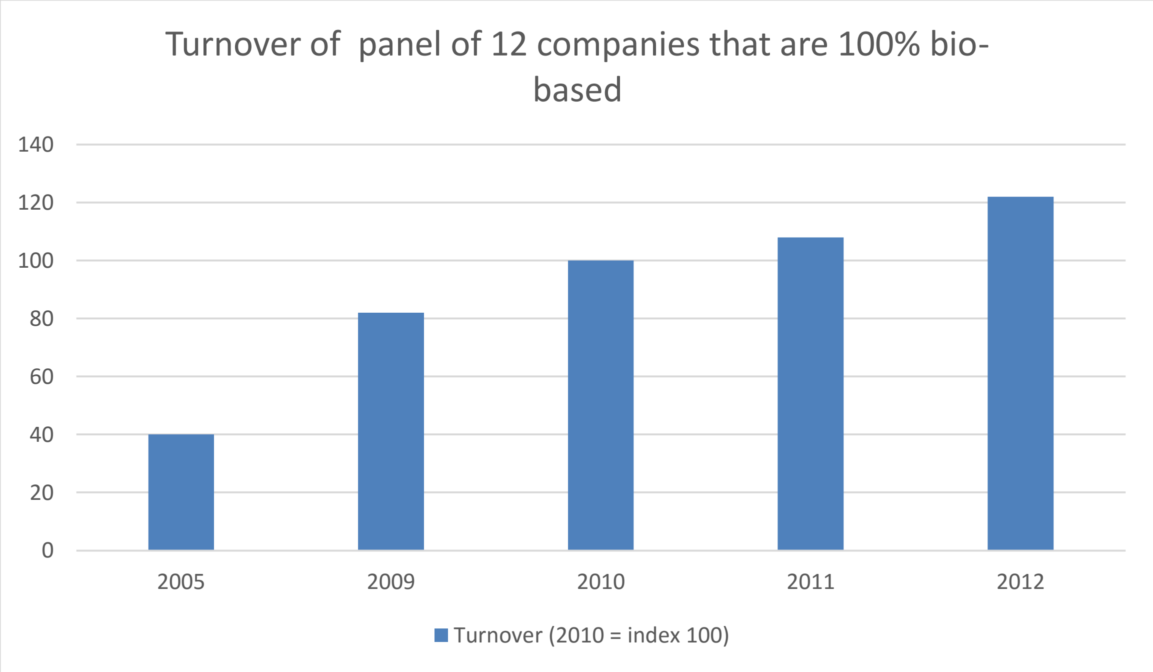
Employment	2007	2011	Growth '07-'11
100% BBE in FDD*	315	570	+80.95%
Ports FDD**	214,035	203,669	-4.84%
Agriculture , and industry (FL/NL)***	940,400	794,100	-15,56%
FDD	5,040,200	5,023,400	-0.33%

*Orbis (2012), *Van Heijst (2012), **NBB en EUR ***Eurostat

Secondly, given the cross-sectoral character of the bio-based economy, ranging from agro-production to the manufacturing of fine chemicals and recycling, the employment figures can be compared with those of the agro and industry sector. The growth of about 81% compares very favourably with the decrease of about 5% in the employment in the ports and the about 16% drop in the agriculture and -industry. It shows the strategic importance of new growth sectors for the Delta. Thirdly, when compared with the total employment in the FDD, only 0.011% turns out to be active in 100% bio-based companies.

Out of the list of 47 companies 100% active in the BBE in 2012, only a few were operating already in 2005. They were selected to make a panel of 12 companies (6 Flemish and 6 Dutch). By analysing their annual financial statements, the evolution of the turnover could be tracked over a longer period. This analysis shows a growth of more than 300% of turnover between 2005 and 2012 (figure 4).

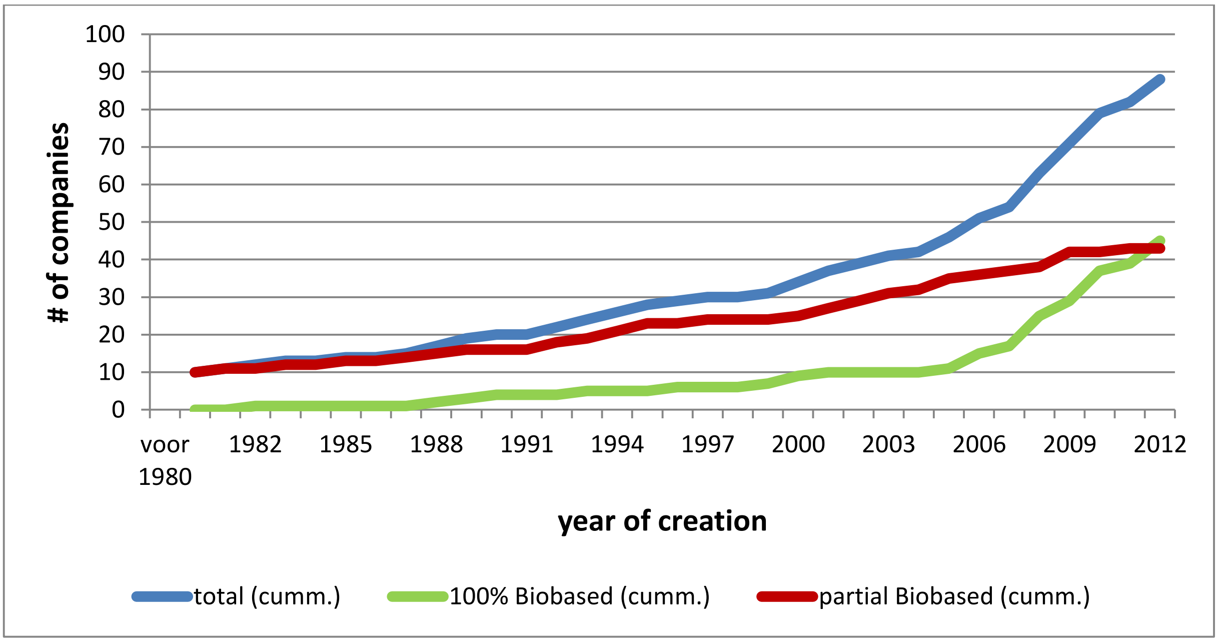
Figure 4. Growth of turnover of 100% bio-based companies



Source : the authors

Figure 5 shows the establishment of firms in the BBE in the FDD. New business formation is an indicator used in cluster theory that is very explanatory. Porter (1990) states that the attractiveness of a cluster can be measured by the number of new companies. Additional activity increases local competition and keeps companies flexible.

Figure 5. Creation of bio-based companies



Source : the authors

New entrepreneurship can be a catalyst for (still unused) knowledge (Audretsch and Keilbach 2008). New business is very important in the start-up phase of a cluster (Feldman and Francis 2004). Table 5 shows that the 100% bio-based companies increased their growth in number from 2006 onwards. From 2011, they even took over from the partially bio-based companies. The figure supports the claim of Rotmans and Horsten (2012) that the BBE in the FDD is still in the pre-development phase.

Location of the BBE: small role for the two major ports

This paper focuses on the bio-based economy in the FDD. The latter embodies the two largest ports of Europe, namely Antwerp and Rotterdam, with yearly throughputs of respectively 185 and 441 million tonnes in 2013 (Port of Rotterdam 2013). In defining this transnational region, this paper follows the definition of the recent co-operation of 6 Dutch and Flemish provinces, namely Antwerp, Northern-Brabant, Eastern-Flanders, Western-Flanders, Zeeland and South-Holland (VN Delta 2014), including the ports of Antwerp, Rotterdam, Dordrecht, Flushing, Ghent, Moerdijk, Terneuzen, Ostend and Zeebruges.

Figure 6 maps all the 92 companies that are found to be active in the BBE in the considered area. From this map, two main observations can be derived. Firstly, it shows that firms are to a large extent concentrated in a specific area. There are small clusters of firms within the FDD. These small clusters include approximately one third of the total number of BBE firms. This development at a regional scale is in line with the observations by the Social and Economic Council of The Netherlands (2010), who stated that development of the BBE should be primarily a “bottom-up” development, controlled by local government bodies.

Figure 6. Map of firms in BBE in FDD

Source: Biobased Economy (2013), Biobased Delta (2013), CINBIOS (2013)

Secondly, the map with the location of firms shows that the two largest ports in the Delta, Antwerp and Rotterdam, play a limited role till now. One would expect that these port complexes also provide a fertile place for the bio-based industry, especially regarding bio-based chemicals or energy. However, it appears that both seaports do not play their expected roles in hosting (important) bio-based companies. The majority of companies that are active in the Rotterdam Port area are mainly large storage, chemical or energy companies for which their bio-based business is just a small fraction of their total activities. In Port Vision 2030, a strategy document of the Port of Rotterdam (2011), the need to use cleaner forms of energy such as LNG, biomass or solar power is acknowledged. Regarding chemical products, it is stated that "*In 2030, Rotterdam will be a premier location, where the transition to bio-based chemicals is in full swing*". At this moment, the bio-based economy is in an early phase in Rotterdam. The other major port in the region, Antwerp, also appears to play a minor role in current developments in the bio-based economy in the FDD till now. Following the list of companies in the database and their location, no bio-based companies are located in the port of Antwerp area. Similar to developments in the port of Rotterdam, several institutions are setting out to (re-)generate old port areas into innovative places for new 'green' businesses and research facilities (Blue Gate Antwerp 2014). In addition, there are large energy and chemical plants that use 'green' feedstock either in co-firing or in their production processes. However, there are no real signs of an active bio-based cluster and the port therefore does yet not play a premier role in this respect, contrary to what one might expect.

The Port of Ghent on the other hand has actively chosen to develop the bio-energy traffic and has supported the creation of the biggest integrated bio-energy production complex in Europe (Belga 2012). The cluster has a production capacity of 300,000 tonnes of biodiesel, 150,000 m^3 of biogas and 240 MW of bio-electricity (Walters and De Mey 2013). The Ghent Canal Zone hosts the Bio Base Europe pilot plant (Bio Base Europe 2013). In the Port of Ostend, a bio-diesel reactor was built with a production capacity of 100,000 tonnes (Proviron 2013).

One can see on the map that many BBE firms are concentrated in specific areas. Three concentrations or clusters can be identified, namely Ghent Bio Energy Valley, Biopark Terneuzen, and Green Chemistry Campus in Bergen Op Zoom. Table 4 gives an overview of the companies active in theses areas, their activities and the stage in the BBE as explained above.

Table 4. Three bio-based clusters in the Flemish-Dutch Delta

Company/institution	Product	Stage
Biopark Terneuzen		
BIO BASE EUROPE	*Center for bio-based innovations*	Other
Cargill (NL)	*Alcohol (3) - Water, starch, steam and heat (circular)*	3, Circular
Dow Benelux	*(Bio-based) chemicals*	3
DSD Betaprocess	*Hydrolyse technology*	2
Ecoservice-Europe	*Biomass transport + supply*	1
Heros Sluiskil	*Waste recycling / biogas, biodiesel*	3, Circular
ICL-IP Terneuzen	*Bromine and recycling*	Circular
Lijnco Green Energy	*Bio-based gas+electricity*	3
Sagro	*Waste recycling*	Circular
WarmCO2	*Heat and CO2 for agriculture*	Circular
Yara	*Fertilizers*	Circular
Electrawinds ReFuel / Greenfuel	*Energy/ Biodiesel*	3
Green Chemistry Campus Bergen op Zoom		
Aiforo	*Conversion (new) wet biomass conversion technqiue*	2
Alpha Enzymes	*Bio-based chemicals*	2,3
Bioclear	*Consultancy and research*	Other
BioTorTech	*Biomass conversion technique / Torrefaction technology*	2
Millvision	*Consultancy and research on bio-based activities*	Other
Progression Industry	*Biodiesel*	3

Retoplast	*Bio-based plastics*	3, Circular
SABIC Innovative Plastics	*Chemical products*	3
	Ghent Bio Energy Valley	
Alco Biofuel	*Bio-ethanol*	3
BIO BASE EUROPE PILOT PLANT	*Center for bio-based innovations*	Other
Bioro	*Biodiesel*	3
Desmet Ballestra	*Production of plants and production processes*	2,3
EDF Luminus	*Heat*	3
Electrabel	*Bio-electricity*	3
Genencor	*Biomass conversion*	2
Oiltanking	*Storage of biofuel*	3
Oleon	*Biochemicals*	3
OWS	*Building bioplant, R&D, waste management*	2
Sea-Invest	*Storage of raw materials*	1
Storaenso	*Biomass producer*	1

Source: Biobased Economy (2013), Biobased Delta (2013), CINBIOS (2013), Orbis (2013), company websites, adapted by Van Heijst (2013)

Biopark Terneuzen is situated in the Ghent-Terneuzen Canal Zone and was established in 2007. Biopark Terneuzen consists of some industrial companies that were already active in the port area before 2007, but are 'greening' their production processes (e.g. Dow Chemical Benelux). From table 4, it becomes also clear that many companies are part of the 'circular' bio-based economy. A lot of companies in Biopark Terneuzen are linked with each other by resource or waste streams. For example, a producer of fertilizers (Yara) delivers its CO_2 to a company specialized in the distribution of heat and CO_2 to the agricultural sector. Biopark Terneuzen accommodates Bio Base Europe, a center for innovation and training focused on a further development of the BBE. In this center, Ghent University, with expertise in industrial ecology and process theory, cooperates with Dutch knowledge institutions like Wageningen University. With the pilot plant based in Ghent, Bio Base Europe is a good example where both Dutch and Flemish parties co-operate .

The Green Chemistry Campus is located near the city of Bergen of Zoom, on the premises of SABIC, a producer of plastics. Sabic acted in the case as the initiator. The large companies and SMEs active in Green Chemistry Campus work closely together in an open innovation environment. The focus is on developing new bio-based technologies and products like performance materials, chemicals and coatings.

From section 3, it can be concluded that the BBE of the FDD in 2013 is in its pre-development phase. In recent years, we observe an increase in the number of firms and related employment. Many projects have been started and the sector is ready for take-off. The next section draws a picture of the future potential of BBE in the FDD.

4. The future of BBE impact on seaports in the FDD

The speed of development of BBE is dependent on the price of bio-based raw materials and the alternatives. Policy can encourage this transition by fiscal support and targets (Carrez and Plasman 2013). This transition will happen slowly over the next 30 years (Biobased Society 2013).

As prices and external costs for fossil materials will increase, while at the same time, through technological evolution and economies of scale, the costs of biomaterials will decrease, bio-based activities have potential for a substantial growth. By 2050, it is likely that 50% of the fossil sources will have been replaced by renewable, biological products (Soetaert 2013). Other sources predict that 25% of the petrochemical production will have become bio-based by 2030 (Vandermeulen, Nolte, and Van Huylenbroeck 2010). This transition will have consequences for the seaports , and for the economy as a whole (Van den Akker et al. 2013).

The growth of the BBE will take place at three levels. Most common but least important in volumes will be the small-scale agro-industrial recuperation of waste streams. The production will often be cyclical, driven by the supply of raw materials. The low value and low density of the raw materials will make transport over longer distances too costly. The resulting bio-based materials can then by transported further up the supply chain by collective transport under milk runs (Annevelink 2013).

Secondly, at a regional level, mid-size Ecoparks will be developed. They will treat a great variety of of bio-streams and adapt their operations to the seasons. The low energy density of the supplies will still impede long-distance transportation. This will guide the location of regional Ecoparks. The parks will use many different technologies to adapt to the cyclical supply which will most often arrive by road (Repriels and Claes 2013).

The third and most voluminous level is the one that will have the biggest influence on seaports, also for the two major ports in the FDD, Rotterdam and Antwerp, even though they still play a minor role today. Projections by the Club of Rome estimate that the port of Rotterdam might lose up to 50% of its throughput by 2040 (Van den Akker et al. 2013). Large streams of homogeneous commodity of biomass origin will replace a part of the fossil materials. Their energy density will be lower than that of the original fossil materials but higher than the other biomass streams of the first two levels. They will make up a large part of the bulk streams of the ports of the future. They will represent an important increase in volumes to be handled by the ports. The energy density of petroleum in MJ/ton is 2 to 2.5 times higher than that of wood. A ton of air dry wood fuel has an energy content of about 15 GJ/t, which is about half of the caloric content of anthracite at 30 GJ/t (Oak Ridge National Laboratory 2014). This needs to be multiplied by the lower density of wood: petroleum has about two times more weight per m³ and the density of wood pellets is with 650 kg/m³ almost half that of anthracite with 1100 kg/m³ (Biomass Energy Center 2014). This implies an increase by a factor four to five in volumes to be handled by the bulk terminals in the ports (Vleeschouwer 2013).

In 2012, the Port of Antwerp handled 5,726,247 tons of coal, which was lower than in the year 2008 where it loaded and unloaded 9,490,343 ton. In the top year 2004, it handled even more with 9,555,519 ton (Antwerp Port Authority 2013). In 2012, this represented 3.10% of all throughput and 43.25% of the dry bulk throughput. Assuming that 50% of this coal throughput is anthracite, and if this would be replaced by wood pellets, this would lead to an additional tonnage throughput of up to approximately 2.9 million tonnes of dry bulk or an increase by 50% of the tonnage in coal handling on top of the habitual increase through economic growth. This would lead to an overall increase of all dry bulk tonnage by 22%. Since the handling of dry bulk is done by technologies which actually handle volumes rather than weights, this increase by 50% of the coal tonnage would actually mean an additional increase by 70% of the cubic metres . This would mean that the additional demand (and also cost) for labour would lead to an increase by 85% to handle the same amount of gigajoules.

These homogeneous streams will change origins with the changing of the seasons. Their origins and composition will be more diverse than of today’s fossil streams. The sources and suppliers of bio-based raw materials are geographically much more diverse than those of fossil materials. Some of them are also considerably closer to or even in Europe as opposed to the sources of fossil fuels in Africa or the Middle-East. They also change across the hemispheres with the seasons. This could lead to a shift in the origins of the streams entering the ports and will result in a reduction of the total amount of distance covered.

The techniques and equipment to handle these dry bulk commodities will need to be adapted to handle increasing bio-based streams. Not only will they be more bulky, but many of them, like wood, pellets are much more prone to damage, pulverisation and humidity

(Vleeschouwer 2013). This will require not only other transfer technologies but also storage techniques. This means that bulk ports who do not acquire these techniques and equipment on time may be left out of the transition.

Bulk ports that would miss this transition would stand to lose over the coming decades an important part of their throughput (Nieuwsblad Transport 2013).

At the same time, this innovative BBE industry may fit into the overall green ports initiatives, whereby green energy for the local industry can be produced locally, BBE fuels can be bunkered to ships, BBE products can benefit from their production location close to the hub which seaports are, etc.

5. Conclusion

The transition to a BBE is still in its take-off phase. This leads many actors to define BBE in different ways, so that a unanimous delineation of the sector, let alone statistics that allow estimating the importance of the sector and its evolution, lack. A common denominator was found in including all flows which lead to an innovative application of food-related flows. Hence, the focus is on the application rather than the source.

The number of companies and the employment involved is still limited but it is rising very fast, which is an indication of the future potential of this sector in creation. As of yet, the main ports in the FDD have little or no activities dedicated to BBE. The identifiable clusters of BBE firms are situated in Ghent, Terneuzen (Zeeland Seaports) and Bergen-op Zoom, not in the mainports. Only the port system Ghent-Zeeland has at the time of writing actively chosen to focus on BBE and has as such created the largest concentration of bio-based energy production in Europe. The mainports of Antwerp and Rotterdam probably have only a limited tonnage of bio-based throughput but this is not fully verifiable since no separate statistical data is kept, so the paper relied on a series of policy documents and studies, as well as on expert interviews. When certain bio-materials go through a port, it is impossible to know whether they are destined to be used as food and feed or as bio-based raw materials. But it is clear that the existing clusters of BBE companies are not (yet) situated in these main ports.

When the transition from fossil carbon to bio-carbon will reach the dry bulk ports, the effect on the volumes will be substantial. It will imply a substantial increase in the volumes that need to be handled as well as modifications to the handling and storage system requirements. The growth of the BBE will take place at three levels. Most common but least important in volumes will be the small scale agro-industrial recuperation of waste streams. The production will often be cyclical, driven by the supply of raw materials. The low value and density of the raw materials will make transport over longer distances too costly. At a regional level, mid-size Ecoparks will be developed, that will treat a great variety of bio-streams and adapt their operations to the seasons. The low energy density of the supplies will still impede long-distance transportation. The third and most voluminous level is the one that will have the biggest influence on seaports.

These observations support policy-makers in dealing with a sector that has a promising potential, but at current is still limited in size and added value. It will need the right approach and incentives. Under those conditions, ports will be able to function as hubs in the international transport of BBE flows, both for raw materials and final products.

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Annex 1: **Interviewed actors**

Mr. D. Carrez and Mrs. C.Plasman	Essenscia
Mr. P. Geertse	Zeeland Seaports
Mr. F. van den Heuvel	Rewin West Brabant & Biobased Delta
Mrs. C. Huisman	Province Zuid-Holland
Mr. T. Repriels en Mr.S. Claes	Van Gansewinkel.
Mr. W. Sederel	Biobased Delta
Mr. W. Soetaert	Bio Base Europe, University of Ghent.
Mr. G. Spork	Dow Chemical
Mr. B. Vleeschouwer	Boerenbond
Mrs. S. Walters en Mrs.S. De Mey	Port of Ghent