Public Deliverable – D1.1

Criteria and Indicators describing the regional bioeconomy

Cambridge (UK), 31 October 2014

Cambridge Econometrics

10/31/2014

Project acronym: BERST
Project full title: "BioEconomy Regional Strategy Toolkit"
Grant agreement no: 613671

Contents

1. Introduction

This paper is the primary written deliverable in Work Package 1 of the BERST project. The purpose of the paper is to:

- deliver an agreed set of criteria which facilitate the development of regional bioeconomy,
- set out the basis for the quantitative analysis, which has been undertaken for two pilot countries (the UK and the Netherlands);
- report on the findings of the quantitative analysis;
- set out the next steps, both within Work Package 1, more broadly for the BERST project and how the work can be continued outside of the BERST framework.

This has been achieved through first bringing together a review of the existing literature and the expertise of the research and regional partners in the BERST project, to ally a formal framework for understanding and evaluating regional bioeconomy with (primarily policy-based) literature and the experiences of regional governments and science parks operating within the EU (Chapter 2). A formal model of the bioeconomy is then outlined in Chapter 3, and used as the basis for the prioritisation of the criteria required for the development of bioeconomy (Chapter 4). The final step is to use this to inform quantitative analysis in pilot countries, where the criteria are mapped to indicators and these indicators collected and analysed for groups of bioeconomy subsectors, allowing us to quantify (in index form) the bioeconomy potential of a given NUTS3 region (Chapter 5). The report concludes by setting out the findings and recommendations for next steps in the project in Chapter 6.

2. Literature review

2.1 EU Policy areas

The literature on the drivers of regional bioeconomy can be broadly classified under the three key pillars of EU policy (Biomass Energy Europe, 2011) namely:

- economy – regional development
- society – social inclusion
- environment – sustainability & resource efficiency

Within these policy areas, the literature classifies and assesses the key drivers of regional bioeconomy. This involves a review of the characteristics of successful bioeconomy and an assessment of these characteristics through measureable criteria as well as developing policy recommendations based on the findings. The literature is largely policy-orientated, although studies often provide empirical indicators for measuring drivers of bioeconomy. The literature also largely focuses on the environmental aspects of bioeconomy, although the economic aspects are also explored to an extent, while the societal characteristics are not explored in any great depth. Most of the literature focuses on the link between the environment and the economy and to a lesser degree society although many studies define environmental challenges as social issues and vice versa (European Commission, 2012 and European Commission, DG JRC, 2013).

2.2 Environment

2.2.1 Resource availability

Bioeconomy development is constrained by the availability of sustainably sourced resources and the efficient exploitation of production factors such as land, water and human capital/labour (European Commission, 2013). Bioeconomy development plays an important role not only in reducing greenhouse gas emissions but also for the potential positive effects on soil, water and air quality all of which are essential to the sustainability of bioeconomy resources. The literature (European Commission, 2012, Teagasc, 2008 and Eduardo and Guy 2012) indicate managing resources sustainably and mitigating and adapting to climate change are important challenges of bioeconomy.

The domestic production of biomass can result in a cheaper supply of biomass than would otherwise be available, however practical experience of the regional partners (amongst whom a number have imported large amounts of biomass rather than producing it) suggest that this is not a fundamental requirement for the operation of a successful bioeconomy; as such while domestic production of biomass might be desirable within certain sub-sectors of the bioeconomy, and should certainly be assessed, it can only be classified as being desirable, rather than essential to the development of bioeconomy.

Land use is the final aspect of resource availability that is identified as a criteria against which the success of a bioeconomy can be assessed. This can refer to the use of land for the production of bioeconomy (as identified above, an important factor in the development of some but not all bioeconomies) or the use of land for other stages of the bioeconomy. However, what is clear is that all bioeconomies that wish to expand need suitable land use policies which allows for the development of new processes and the establishment of new firms, and it is therefore classed as a key criteria. Primary examples of this include soil management, climate change adaptation, water management and nutrient management.

2.3 Economy

2.3.1 Clusters

A number of factors are important drivers of clustering in bioeconomy. This includes the transfer of international commercial biotechnology experience among employees and support for closer commercialisation with technology transfer from research (Europe INNOVA, 2008). Other factors related to clustering are financing, industry mix and governance - all of which are drivers in their own right. Among the benefits of clusters are lower transaction and coordination costs to bring appropriate actors together as well as the potential for innovation in for example in smart systems and service development, while risks include insufficient economic diversification, lock-in to long-term investments, over-reliance on key firms and the effectiveness of public sector identification instruments (OECD, 2007).

2.3.2 Finance

Private sector involvement in bioeconomy can be encouraged by mitigating risk through establishing methods of identifying technologies with high potential. Microfinancing of small companies is one potential support instrument or even providing parallel investments in early stages of development. Subsidies also offer firms an incentive to adopt new technologies and can be implemented via a guarantee of large scale of orders (UNIDO, 2001) as well as by ensuring the optimal leveraging effect in terms of final implementation. In addition, the availability, technology oriented knowledge base and proximity of financial institutions, sustainability and the type of funds and barriers to access are also key factors affecting the development of bioeconomy (PwC, 2011).

Bioeconomy includes also a high share of advanced technologies and processes. To convert these to commercial success requires investment, first on a small scale for pilot and demonstration plants and then at full-scale. The decision on investment depends upon the perceived balance of risk and reward and this is a complex assessment. Scaling up plant from the laboratory to a pilot stage is risky; the rewards at this stage are uncertain, the expenditure is relatively modest, but likely to exceed the capacities of most SMEs. Scaling up from pilot plant to commercial scale involves less technical uncertainty, but the outlay is greater and the risk is still high. At this stage, in addition to technological risk there is market risk also; the product may not sell, or may not be competitive with rival products; it may even sell at a premium because it is bio-based, but this cannot be known for certain before investment is made.

The poor availability of venture capital in Europe is a partial driver of the investment problem in those sectors characterized by high perceived risk. Europe has a very large capital base, but a low appetite for risk. Venture capital is not as easily available as in the US and tends to be mainly in the UK. In 2011, €16.5 billion of Private Equity and Venture Capital funds were raised in the UK, next was France and Benelux with €8.6 and the Nordic countries with €8.2 billion[1]. A substantial part of these funds originated from North America. The relatively young venture capital industry in Europe has had some remarkable successes, but its presence in business finance in Europe is still much lower than in the US. Through the first six months of 2012, 82 U.S. venture funds raised $13 billion while 27 European venture funds raised $2.3 billion respectively, according to Dow Jones[2]. To some extent this matter can be addressed through the risk-sharing instruments available under FP7 and Horizon 2020 and the greater emphasis within Horizon 2020 on innovation. Still there is a strong need for public private partnerships that can help minimise the risks and facilitate the uptake of innovative, efficient value chains in the future bioeconomy.

2.3.3 Infrastructure

Good and ideally complementary infrastructure is important to achieve the required synergies and optimise logistics that will facilitate the success of the bioeconomy (PwC, 2011 and European Commission, 2012). The literature also suggests that investment in supporting infrastructure is important to minimise negative impacts on environment and also to avoid inappropriate trade-offs. Furthermore, adopting active management approaches to meet regional cohesion objectives and also nature conservation are desirable characteristics of bioeconomy. Possible approaches to achieve this include resource efficiency, decoupling and sustainable growth (European Commission DG Regio, 2013).

[1] Yearbook 2012: Activity Data on Fundraising, Investments and Divestments by Private Equity and Venture Capital Firms in Europe, European Private Equity and Venture Capital Association

[2] Venture capital fund-raising on track to surpass 2011, Dow Jones, Press Release, 9th July 2012.

Cross-industry collaboration in R&D is also a key factor in the success of bioeconomies (Formas, 2012), along with different types of collaborator and integer business models (OECD, 2009). Funding can also be provided to encourage collaborative work (Bio.be, 2013). The future bioeconomy can only happen if industrial leadership is supported by relevant fundamental research and applied research. Industry need to collaborate. The assignment cannot be done by single companies or by single countries. A combined effort is required and clusters are very important in respect to the future competitiveness of the European bioeconomy.

2.3.4 Industrial culture

Changes in production and suppliers of intermediate products may be needed for the transition to bioeconomy. There is a need to demonstrate technologies and to build some flagship plants. Providing continued support for the demonstration of products, systems and services other than fuels and energy technology solutions are beneficial to the development of bioeconomy. Offering support to small and medium-sized enterprises for the commercialisation of new technologies is also an important driver (Formas, 2012). Furthermore, the existence of large companies and SME start-ups/spin off survival also plays a role in developing bioeconomy as well as a non-risk adverse entrepreneurial and networking culture (PwC, 2011). The importance of entrepreneurship (and policies to ensure entrepreneurship is a desirable career path) is also highlighted (European Commission, 2011).

2.3.5 Innovation

Europe enjoys a strong, but far from dominant position, in the science of biotechnology. Europe hosts fifteen of the top fifty universities in biochemistry, genetics and molecular biology and twenty-three of the top fifty universities in agricultural and biological science. New technologies often draw on a broad base of scientific knowledge; an OECD study shows that that material science makes the single largest contribution to clean energy, followed by chemistry and physics; energy and environmental science only account for 10% and 1.7% respectively. The same study shows that universities are among the top players in the commercialisation of key enabling technologies such as biotechnology and nanotechnology, emphasising the need for effective collaboration between academia and industry[3].

The two main drivers of the innovation deficiency are the volume of research funds and the fragmented nature of research. Recent data on research expenditures in the field by Europe and its competitors do not appear to be available. The definitional problems in this area are particularly obscure (what part of agriculture, forestry, chemistry, pulp and paper, pharmaceuticals to include). The OECD has assembled estimates for 2005, drawing on the findings of the FP6 BioPolis project for European data[4]. The comparison suggests that the US provides far greater public funding for biotechnology than other developed countries. Public funding within the OECD area for all types of biotechnology research in that year was approximately €28.7 billion, of which Europe accounted for $4.1 billion, other OECD countries for $1.4 billion and the US for $23.1 billion. The US therefore accounted for 81% of public expenditure by developed countries[5]. Private sector expenditures in biotechnology were estimated by the OECD to be less than public expenditures and again dominated by the US. The dominance of the US is partly explained by large expenditures on research on GM crops and on healthcare; it is not clear how expenditures on research in bio-industry in different countries compares. The Biopolis project made qualitative comparisons of US and European performance and concluded that "with respect to most performance indicators, the United States performs at a similar level to the best European countries. However, the position of Europe as a whole seems less favourable when compared with the United States"

Collaboration is also a critical factor in successful innovation. Collaboration is an important feature of the European research effort, but it is limited by the fragmented nature of activity divided

[3] Science, Technology and Industry Scoreboard 2011, OECD 2011
[4] Inventory and analysis of national public policies that stimulate biotechnology research, its exploitation and commercialisation by industry in Europe in the period 2002–2005, BioPolis, 2006
[5] The Bioeconomy to 2030: Designing a Policy Agenda, OECD, 2009

between European and national programmes with restricted interaction. Scientific production relies on critical mass and effective networks of knowledge sharing that are more difficult to create in Europe than in North America. The need for collaboration along the entire value-chain and between industry and academia was stressed in the conclusions of the BioPolis project, "nations wishing to sustain or improve their commercial performance in biotechnology will not be successful if they focus their supporting activities only on functions of the innovation system which are directly related to commercialisation. Rather, it is important to take a holistic approach towards the bioeconomy system, taking care of both the scientific and the commercialisation sub-systems".

An element of high importance for the European entrepreneurial system is also the availability of support to small and medium-sized enterprises for the commercialisation of new technologies is also an important driver of bioeconomy (Formas, 2012). Of particular importance is the diffusion of biotechnology knowledge and expertise (OECD, 2005). Advances and convergence in technologies will also be a major future driver (Europe INNOVA, 2011). Finally, the literature suggests that the EU does not effectively capitalise on its own R&D results (European Commission, 2009).

2.3.6 Macroeconomic trends

Consumer preferences for bioeconomy products is key to the successful development of the sector (European Commission, 2013 and Teagasc, 2008), including public support for bioeconomy products (explored further below). A possible approach to stimulating consumer preferences for bioeconomy products is via incentives for consumption and production of new products. Household income levels also play a role in the development of the sector (Bio.be, 2013).

2.4 Society

2.4.1 Demographics

Demographic factors have been highlighted as important to bioeconomy success, these factors include population growth, education and human capital (Teagasc, 2008) and (SAT-BBE, 2013). Global population growth by 2050 is also a strong driver as it is estimated to lead to a 70% increase in food demand; demand for found increases faster than population because of improved diet and especially because more meat is eaten[6]. Improvements in agronomic science will help relieve that stress, but security of food supply is already a serious concern in many different ways and it is only likely to get more acute as the global population continues to grow, as climate change continues to disrupt historic practices of husbandry and as pressure on biological resources from other demands increases. Public awareness and consumer behavioural aspects are expected to be important drivers for the bioeconomy.

2.4.2 Institutions

During the last two decades substantial effort has been put in the development of the science base which supports the different sectors of the bioeconomy. The existence of renowned universities or research institutes with renowned researchers as well as appropriate processes to increases the extent of collaboration, knowledge transfer and validation in new business cases all will play important roles in the success of bioeconomies (PwC, 2011). The scarcity of natural resources and the climate change implications represent both a driver and a challenge for the scientific community to develop smart and flexible solutions at certain deployment timeframes and for different implementation scales (from local to regional and international).

2.4.3 Governance/regulation

The regulatory system can be utilised to improve both the efficacy and the safety of biotechnology products. Intellectual property rights can encourage firms and universities to develop business opportunities driven by social and environmental factors. Moreover improving governance by including citizens and firms in dialogue with government and one another is an important driver of bioeconomies (OECD, 2009). The governance of cluster initiatives is also a key driver for

[6] How to feed the world in 2050, FAO 2009

bioeconomy performance with trust and involving local influential government decision makers cited as important for successful bioeconomy clusters. Government policy also affects performance indirectly by affecting the objectives and processes of cluster initiatives further highlighting the importance of good governance. Another key success factor is driven by the appropriate skills of the facilitator, particularly relating to their skills in networking of contacts. Furthermore, integrating the cluster initiates in a broader microeconomic policy is also important for their success (Solvell, Lindqvist and Ketels, 2003).

2.4.4 Public acceptance

Public acceptance for biotechnology products is a key driver in their take-up among consumers. This can achieved through communication and education of safety and other issues relating to these products (Clever Consult, 2010). An important element of this is to create an ongoing dialogue among governments, citizens and firms (OECD, 2009). In the transition towards a bioeconomy it is also important to have the support of the public in particular for the waste sorting at source as this may be needed as well as an open and positive uptake of new technology.

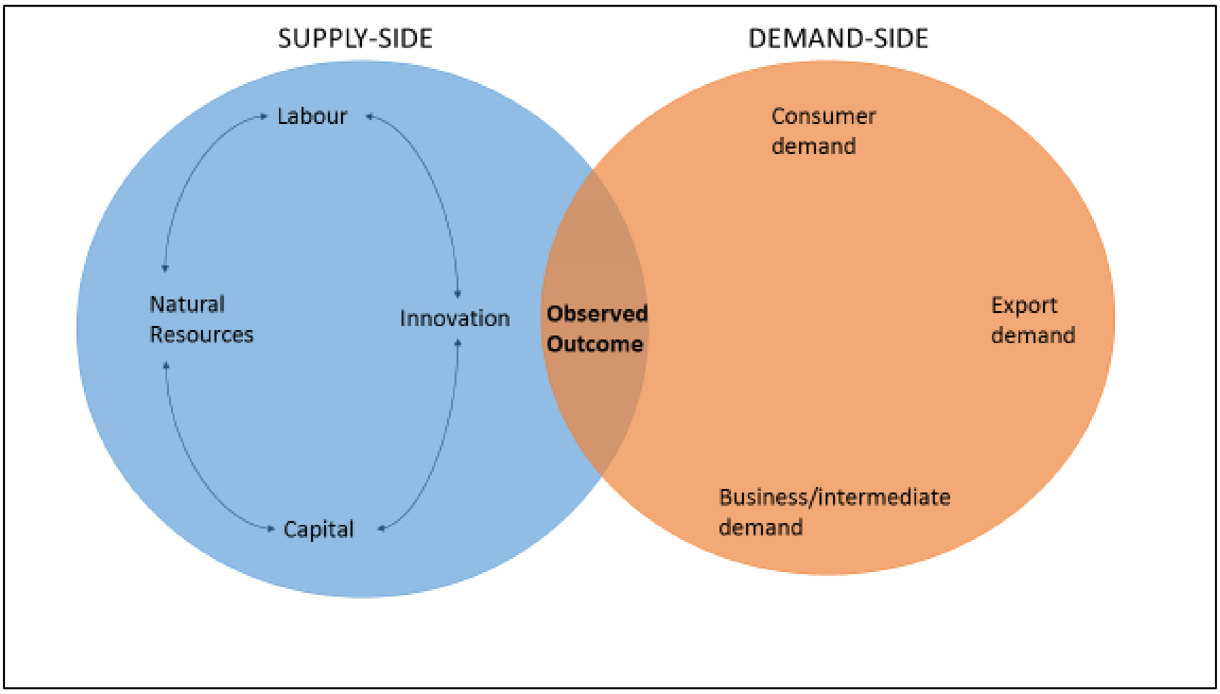
3. A model of the bioeconomy

A small number of the reviewed papers included a model of the bioeconomy. Having a clearly defined understanding of the operation of the bioeconomy is key for understanding how drivers and criteria for bioeconomy development are prioritised, and how the criteria assessed in this Work Package link to the instruments and measures that are explored in Work Package 2.

The most relevant model of bioeconomy reviewed in the literature was the SAT-BBE project (2013). This model concentrates on the demand and supply of biomass, and identifies the key drivers that feed into the bioeconomy; however, it does not break down the demand and supply-sides of the market in any great detail. An alternative model of the bioeconomy is presented in Regional Biotechnology (PwC, 2011), although this focuses solely on the supply side.

It is clear from the reviewed literature that an all-encompassing model of the bioeconomy must consider both the demand-side and supply-sides of the market for bioeconomy. A successful bioeconomy is one that maximises both the supply-side and demand-side of the market to ensure both that it is able to produce, and sell, bioeconomy products and services. Bioeconomy as a whole can be split into three distinct market segments; the sectors that supply biomass, those that convert biomass into intermediate products and those that bring biobased end-products to market (see Discussion Paper 3 for more details). Clearly each of these has different priorities in terms of the supply and demand for products. The model should take account of the factors of production (which affect the supply side) and the demand for bioeconomy both within and outside of the region (i.e. the demand side). Adopting a 'factors of production' approach to the supply side enables us to evaluate separately the criteria related to each element of the supply-side. Here we consider separately the three classical factors of production: land (or, in a bioeconomy context, natural resources), labour (meaning human capital) and capital (describing the processes used within the bioeconomy); as well as a fourth factor, innovation, which while not traditionally a factor of production in itself, nonetheless plays a major role in how the three factors interact to determine the overall supply of bioeconomy products. On the demand-side we have consumer, export, and business demand combined. This gives us the following overall framework:

Figure 1 Model of the operational bioeconomy



Source: Cambridge Econometrics

The observed outcome for bioeconomy is the area in which the supply-side and demand-side overlap; therefore the key to a successful bioeconomy is to maximise the overlap between these two. Each of the criteria that are identified in the literature (and which we expand upon below) are aimed at measuring the state of the regional market for bioeconomy: either through capturing the state of the supply side (i.e. one of the four identified factors of production), the demand side (i.e. the identified markets for bioeconomy) or the interaction between the two (e.g. the point at which demand and supply intersect).

This model does not pre-suppose an outcome. It is possible for demand and supply to have no overlap without policy intervention, and indeed, in regions with little or no existing bioeconomy, a key question to be answered through this project is where specific strategies should be targeted within this model to maximise deployment of the regional bioeconomy.

The regional dimension to this model is primarily supply-side. In examining the regional bioeconomy, we are interested in the capability of the regional economy to supply bioeconomy-based goods and services (and therefore to create regional economic activity), and to make connections with the industry that use biomass inputs for making their intermediate or end-products. The demand for bioeconomy may come from within the region, but may come from elsewhere within the nation, within the EU or through export demand. While regions are clearly demanders of the products produced within the bioeconomy. We do not assume that even those bioeconomy subsectors which require inputs from other parts of the bioeconomy must have supply chains within their own region. However clearly in some cases supply chains will be highly localised.

The benefits of this model are that it provides a clear link between economic theory (with factors of production, and considerations of factors that affect the interface and demand and supply) and the existing literature on bioeconomy, which focusses almost exclusively on the impact of policy without reference to the market for bioeconomy. Later in this paper we bring together the two approaches to identify, for each driver of bioeconomy, where it fits within the two alternative approaches.

4. A framework for the criteria of successful regional bioeconomies

In developing a framework classifying and prioritising the criteria for a successful bioeconomy region, we have sought to bring together the literature reviewed, the market framework and the input of regional partners, as well as the expertise of the project team. As part of this widening of scope, we questioned the regional partners within the project to understand what has driven development in their bioeconomy, how that development has taken place and the drivers they expect to be key in the future. This was done outside of the theoretical structure presented in the literature review, so that we could use the experiences of the regional partners to 'check and challenge' our theoretical understanding. The experiences of the regional partners were particularly useful in allowing us to prioritise (or rank) the criteria of bioeconomy within our framework, and the findings are set out below.

We rank the criteria according to three levels of importance;

- *essential* criteria, without which it would not be possible to develop bioeconomy;
- *key* criteria, which play a very significant role in development; and
- *desirable* criteria, which can facilitate additional growth (sometimes in specific subsectors of the bioeconomy only), but which are not necessary for the development of bioeconomy.

We considered alternative methods of evaluating the criteria (for example, using the Qualitative Comparative Analysis (QCA) method to separate out only 'necessary' and 'sufficient' criteria), but based only on literature and project team expertise there was insufficient information on which to base such strict criteria. In the next chapter, where we move to quantitative assessment of the regional bioeconomy, we use a different weighting system; however the identification of relevant criteria during the quantitative analysis is heavily informed by the theory-based work undertaken in this chapter.

The reasons for this ranking of criteria are both to aid our understanding of the regional bioeconomy in the broad sense and, within the specifics of the project, to link this Work Package with subsequent Work Packages (particularly WP2 on instruments and measures). By prioritising the criteria of the bioeconomy, once links have been established between these criteria and the instruments and measures, the combined database will be able to assign priorities to instruments and measures (both those adopted by a particular region and to highlight gaps in existing regional strategies). Thus the prioritising of criteria adds significant benefits to the end outputs of the BERST project.

This work presents the first step towards the identification of performance indicators against which regional bioeconomy performance can be measured (which is covered in the next chapter). Our approach in this section is to ally the EU strategic priorities (through the three pillar approach) with the drivers of the bioeconomy market identified above. Below is a brief discussion of each of the identified criteria, followed by a summary table setting out each criteria, the market driver which they interact with and our qualitative ranking of their relative importance.

4.1 Environmental criteria

4.1.1 Resource availability

Resource availability is clearly classified under natural resources in the supply factors of our model of the bioeconomy. Whether from domestic production or through imports, the availability of sustainably sourced biomass is the single most important driver of bioeconomy development. Both from the literature and the practical experiences of regional partners it is apparent that without biomass a functioning bioeconomy is impossible. Therefore biomass availability is the first criterion identified, and is classified as an essential criterion of bioeconomy development.

The domestic production of biomass can result in a cheaper supply of biomass than would otherwise be available. However from practical experience of the regional partners (amongst whom a number have imported large amounts of biomass rather than producing it), while domestic production of biomass might be desirable within certain sub-sectors and should certainly be assessed, it can only be classified as being desirable, rather than essential to the development of bioeconomy.

Biomass availability is the final aspect of resource availability that is identified as a criteria against which the success of a bioeconomy can be assessed, as it is the base for deploying a regional bioeconomy. Biomass can either be produced domestically or imported. In terms of indicators, we concentrate on the former, as while there is data available on land use (from which we can imply information on domestic production) there is no data on imports of biomass. Land use can refer to the use of land for the production of bioeconomy (as identified above, an important factor in the development of some but not all bioeconomies) or the use of land for other stages of the bioeconomy.

4.2 Economic criteria

4.2.1 Clusters

The literature review highlights the role of clusters in successful bioeconomy and we group this, as a contributor to the innovation capacity in the region economy, as clusters pool knowledge and resources in extending the productive capabilities of firms via greater innovation. This is further reinforced by the experiences of the regional partners, whom all have their bioeconomy concentrated within small geographical areas. This highlights the importance of successful clusters to a successful bioeconomy. The key criteria for the assessment of the strength of a cluster relate to size and management: specifically, the size of the cluster (to be measured in terms of number of businesses or number of employees), the management of the cluster itself, and the cluster governance (i.e. the support provided by local/regional/national government in setting up and managing the cluster, as well as any cluster-friendly policies that are introduced). The size of cluster does not seem, in the experience of the regions, to be a major deciding factor in the performance of the bioeconomy, so can be said to be desirable, while cluster management plays a major role in successfully establishing a bioeconomy so is a key criteria. The role of cluster governance, in helping to fund and maintain the rate of development of clusters, can be seen to be key in the continued growth of the bioeconomy.

4.2.2 Finance

The development of bioeconomy is further aided by availability of funding to companies and new technologies via instruments such as microfinancing and guarantees of large scale orders and it should be noted that finance models vary across the EU (e.g. German bank-based versus UK market-based models). These are desirable instruments in developing innovation and economic growth in bioeconomy and should directed towards innovation in particular. While bioeconomy may succeed on self-financing and existing market funding, schemes targeted at high-potential innovative companies will reduce the restraints that lack of access to funding places on the growth of firms. Favourable proximity to financial institutions is also a desirable criteria of bioeconomy, particularly for smaller firms, as this improves access to finance (whereas large, more widely known, firms may be able to access finance regardless of proximity). Financing is classified under capital in our model of the bioeconomy.

4.2.3 Infrastructure

Infrastructure refers to the capacity of the transport, communications, complementary industries and utilities network in and around a bioeconomy. Therefore, this is classified as capital in the model above as the factor of production which increases both the efficiency and the productivity of other factors of production. There are three potential areas for exploitation of infrastructure; a strong transport infrastructure (road, rail, water, air) allows for the low-cost import and export of biomass and other bioeconomy products, as well as increasing the viable commuting distance for a potential workforce, while a strong communications, complementary industries and utilities infrastructure allows for the easy sharing of existing technology and uptake of innovations; finally a strong environmental infrastructure, able to mitigate environmental impacts, will aid sustainability of biomass supply and reduce long-term externalities. Up to a certain point, the first two are essential to the development of bioeconomy (e.g. a science park without road access or internet would struggle to be successful), but beyond a certain stage of development all of these criteria can be seen as being desirable. Infrastructure also plays a key role in determining the first of the economic criteria, clusters, in that high quality clusters have to be supported by strong infrastructure.

4.2.4 Industrial culture

Industrial culture covers a large number of characteristics of the business base of a region and is classified under the innovation category of our model above. It includes the innovation culture; the rate of formation of SMEs (which the literature suggests is a key criteria for strong bioeconomy development as SMEs can fill 'gaps' in the value chain and are more prone to innovation); and the presence of multinationals (which can promote growth of the bioeconomy through the potential for large-scale investment). The economic history of the region is a key characteristic which determines both the current level of development of the bioeconomy, but also current levels of capital and infrastructure which influence both the market for the products as well as the potential for investment. Industry culture also encompasses the potential for collaboration between firms to pool resources in introducing innovative products to the market which is a desirable criteria. Finally, a key criteria of bioeconomy development is an entrepreneurial culture which is not risk adverse and includes both a willingness to start new companies as well as a willingness for investors to take risks on high-potential enterprises.

4.2.5 Industry mix

The industry mix of a bioeconomy can play a desirable role in developing bioeconomy. Collaboration across industries such as agrifoods and chemicals in research and development including collaborator and integer business models augment existing innovation successes and improve the performance of the bioeconomy. This is classified under the innovation category of our model.

4.2.6 Innovation

Innovation is a key criteria in the growth and establishment of bioeconomy and its importance is reflected in its classification as a factor of production in our model above. While bioeconomies may exist on current technologies, the growth of new technologies is key to future growth and in sustaining the bioeconomy against competitors. In particular, the literature notes commercialisation of innovative technologies as well as the diffusion of technology as key criteria in driving a bioeconomy to effectively capitalise on R&D activity. The ability to absorb the diffusion of technologies is important in allowing growth convergence with the most innovation economies while the commercialisation of innovative technologies is key to generating the growth of the bioeconomy at the technological frontier. The extent to which R&D focuses on key enabling technologies (KETs) is a desirable criteria of bioeconomy in that this increases the effectiveness of innovative activity and increases the likelihood that the innovative technologies will be commercialised. Innovation can also take other forms; for example organisational or social innovation, where the development of new services in support of the bioeconomy are a criteria for successful future development. These can also be seen as being desirable in a region wishing to develop bioeconomy.

4.2.7 Macroeconomic trends

The demand for bioeconomy products is an important criteria and falls into both the consumer and business demand classifications in our model. The literature highlights the role of consumer preferences in the development of bioeconomy (for example, the global emphasis on climate change driving consumers to more sustainable energy sources) and suggests consumption and production incentives to stimulate demand. Linked to this is public support and acceptance of bioeconomy products. Alleviating safety concerns about bioeconomy products and including the public in the discussion on the desirability of bioeconomy products will improve the ability of firms to both produce products appropriate to consumer preferences in the market and grow the market for new products based on consumer desires and/or changing perceptions about the products. Another desirable criteria is changes in household income which not only increases general consumer consumption but also the preferences for new and innovative products.

4.3 Social criteria

4.3.1 Demographics

Finally, a range of demographic factors are desirable criteria of bioeconomies. Larger markets via greater population growth can stimulate greater demand and is classified as consumer demand. In addition, greater public acceptance for bioeconomy products and a more skilled labour force by increasing levels of education and human capital increases both the productivity of the bioeconomy sector and the demand for their products with can be classified under both consumer demand and capital in our model above.

4.3.2 Academic Institutions

Clustering and innovation within bioeconomy is augmented further by desirable criteria such as containing high quality universities or research institutes. Collaboration between institutions and industry further increases innovation output. Beyond this, the quality of those collaborations and research institutes are clearly paramount to successfully benefitting from these criteria; and this will be explored further in the work to quantify these criteria later on in the BERST project.

4.3.3 Governance/regulation

Regulation of the safety of bioeconomy products with clear technical standards (to reassure producers and consumers) as well as stronger intellectual property rights securing the incentives to innovate are key criteria. Standardisation and methods of 'locking in' markets, along with the enforcement of intellectual property rights, provide a large degree of certainty to private companies operating (or wishing to operate) in the bioeconomy sector. Governance is an essential criteria for bioeconomy; activities range from offering subsidies to producers to including key stakeholders such as citizens, firms and influential government decision makers in the development of bioeconomy which links to the public acceptance of bioeconomy products. Feedback from regional partners is that without this government intervention (particularly the financial measures) there would, in the vast majority of cases, not be a functioning market for bioeconomy products. Finally, integrating cluster initiatives in the broader microeconomic policy particularly in trade policy is another desirable criteria as well as prioritising biotech at the regional and/or national level.

4.3.4 Public acceptance/Attitude

Public acceptance of bioeconomy products is a desirable criteria and feeds into other drivers such as safety issues which involves effective governance/regulation as well as consumer preferences and can enhance the take-up of bioeconomy products. This falls under consumer demand in the model above.

4.4 Summary

The analysis above outlines the decisions made in prioritising criteria of the bioeconomy, based upon the literature review and how regional economies (both bioeconomy and other sectors) develop. Each criterion is matched with a bioeconomy model characteristic and a market model driver, agents that help the corresponding models function. Linking the criteria to these characteristics and drivers may indicate what role each criterion plays in the models or in other words, what aspects of the bioeconomy or market it influences. The analysis is summarised in Table 1 below.

Table 1 Summary of criteria and importance ranking

Criteria	Characteristics	Market model driver	Importance of criteria		
			Essential	Key	Desirable
Environmental criteria					
Biomass availability	Resource availability	Natural resources	✓		
Domestic production of biomass	Resource availability	Natural resources			✓
Land use	Resource availability	Natural resources		✓	
Infrastructure	Infrastructure	Capital	✓	✓	
Economic criteria					
Cluster size	Clusters	Innovation			✓
Cluster management	Clusters	Innovation		✓	
Cluster governance	Clusters	Innovation		✓	
Commercialisation of innovative technologies	Innovation	Innovation		✓	
Diffusion of technology	Innovation	Innovation		✓	
KET R&D focus	Innovation	Innovation			✓
Consumer preferences	Macroeconomic trends	Consumer demand			✓
Public support and acceptance	Macroeconomic trends/Public support	Consumer demand		✓	
Household income	Macroeconomic trends	Consumer demand			✓
Availability of funding	Finance	Capital			✓
Proximity to financial institutions	Finance	Capital			✓
Rate of SME formation	Industrial culture	Innovation		✓	
Presence of multinationals	Industrial culture	Capital/ Innovation			✓
Economic history	Industrial culture	Capital		✓	
Collaboration	Industrial culture/Industry mix/ Institutions	Innovation		✓	✓
Entrepreneurial culture	Industrial culture	Innovation		✓	
Quality of workforce	Demographics	Labour			✓
Social criteria					
Prominent universities or research institute	Institutions	Innovation			✓
Regulation	Governance/ regulation	All		✓	
Intellectual property rights	Governance/ regulation	Innovation			✓
Governance	Governance/ regulation	All	✓		
Trade policy	Governance/ regulation	Consumer & business demand			✓
Size of population	Demographics	Labour/ consumer demand			✓

5. Criteria and indicators for identifying the potential of regional bioeconomy subsectors

It is apparent from the work outlined above and the Milestone report M1, that the bioeconomy is comprised of different sectors at different stages of the supply chain. BERST Discussion Paper 3 identifies 16 subsectors which form the basis of the quantitative approach that we take forward in Work Package 1 and which will also be used as a basis for the conducting of case study and good practice analyses in Work Package 3 and the formation of regional profiles in Work Package 4. Table 2 summarises these subsectors.

Table 2 Bioeconomy subsectors

No.	Sectors that supply biomass	Examples of biobased intermediate and end-products produced
1	Arable and Livestock	Crops, animal fats, milk, meat waste
2	Horticulture	Plants, flowers, waste
3	Fishery, aquaculture	Fish, algae, waste seaweed
4	Forestry	Wood, pellets
5	Biomass importers	Biomass, waste, pellets
No.	Sectors that convert biomass into intermediate products	Examples of biobased intermediate products produced
1	Biorefinery and co-digesting	Bioethanol, biodiesel, proteins, enzymes ; biogas
No.	Sectors that bring biobased end-products to market	Examples of biobased end-products produced
1	Food	Crops, vegetables, fish, fruit, meat, dairy (and waste as intermediate product)
2	Feed	Animal feed (and waste as intermediate product)
3	Construction	Natural fibre, based building materials, timber
4	Chemical and polymers	Bioplastics, biocosmetics, biomedicals, biopharmaceuticals, natural rubber, biocoatings, biochar (soil improver)
5	Pulp and paper	Paper, fibres
6	Textile and wearing	Clothes, wearing, shoes
7	Solid energy	Wood pellets, woodchips, logwood, peat
8	Gaseous energy	Bioenergy (from manure, sewage sludge, plant)
9	Liquid energy	Bioenergy, blended fuels
10	R&D services in biomass	Patents, biotechnics, applications, installations

Source: BERST Discussion Paper 3: Subsectors in Bioeconomy in BERST (2014).

Section 5.2 sets out the approach that we have taken to identifying the key criteria in each of these subsectors, and collecting data to assess the current status and the future potential in regional economies. Current performances are measured and evaluated (primarily using employment and firm number data), but these metrics give only a possible interpretation of the current state of the bioeconomy. Even when evaluating data at a 4-digit NACE code level, a large proportion of the activity is likely to be in 'traditional' biobased sectors (e.g. primary, food and feed), rather than specifically biobased focussed (e.g. chemistry, energy). As a result, the evaluation of future potential is given more weight in the analysis that follows. The quantitative analysis itself is contained in a series of spreadsheets which act as an annex to this main report.

5.1 Method and data collection

The earlier work in this report outlines a general structure of the bioeconomy, and the criteria of that structure. In order to identify criteria that are relevant for describing the bioeconomy potential, we group the 16 subsectors identified above into 8 groups with shared characteristics, as shown in Table 3.

Table 3 Quantitative analysis groupings

No.	Bioeconomy grouping	Subsectors included (if more than one)
1	Primary biomass sectors	Arable, Livestock, Horticulture, Fishery, Aquaculture, Forestry/wood
2	Food and feed processing	Food processing, Feed processing
3	Construction	
4	Chemical & polymers and biorefinery	Chemicals & polymers, Biorefinery
5	Pulp & paper	
6	Textiles & clothing	
7	Energy	Solid energy, Gaseous energy, Liquid energy, Co-digesting
8	Biotechnology	R&D services in biomass

Source: BERST Discussion Paper 3: Subsectors in Bioeconomy in BERST (2014).

Based on the list of criteria for describing a successful bioeconomy (Table 3), we explored the quantitative indicators by prioritising them for each group of subsectors, according to their individual characteristics. The most important indicators from these unique rankings are then separated into indicators of current performance and indicators of potential. All **indicators of current performance**[7] reflect how developed the sectors already are, whereas the **indicators of potential**[8] can be regarded as describing the bioeconomy potential of the sectors. This work has currently been undertaken for the UK and the Netherlands, as pilot studies. These two case studies will allow us to assess the validity of the model that we have set up for each group of subsectors, and propose a methodology that can be extended further in the future, in principle for any other regions, if the relevant input data can be secured.

Data for NUTS3 regions, or the lowest regional classification available (either for NUTS2 or NUTS1 regions) are collected mainly from Eurostat and national sources.

A suitable proxy has been used where data are not available for the desired indicators or at the desired geographical level. All data are then indexed against the national level, based on the understanding that regions within the same country are likely to share similar characteristics. For example, a largely agricultural country would expect to have regions with higher-than-average agricultural land use. Also regions within a Member State are likely to be in competition for funding and access to markets; therefore comparisons against the national average show relative specialisation in this context:

- a score of more than 100 implies that the region outperforms the national average;
- a large number of index scores exceeding 100 suggests the region either has a more intensive sector or has more potential to become specialised in it than the nation as a whole.

The higher the index, the greater the degree of specialisation. In the aspect of potential, indicators with scores far exceeding 100 can be important bioeconomy drivers of the sector and improving them is likely to also develop the sector itself. Table 4 outlines data sources used to produce the UK regional bioeoconomy indicators, some of which also used for the Netherlands. A full list of all sources for both UK and Netherlands analyses is detailed in Annex A.

[7] Indicators of current performance are represented by regional employment in the group of subsectors as a percentage of total regional employment (i.e. a measure of regional specialisation). This is discussed further in Annex B.

[8] Indicators of potential are calculated as an arithmetic average of all indicators of future potential, with different indicators selected for different subsectors depending on their relevance. This is discussed further in Annex B.

Table 4 Data sources for UK analysis

Type of indicators	Type of source	Source(s)
Employment	National	Business Register and Employment Survey (BRES)
Businesses/SMEs	National	UK Business Counts; ONS Business Demography
University	National	Research Assessment Exercise
Exports	National	HMRC Regional Trade Statistics
R&D expenditure	European	Regional Innovation Scoreboard
All other indicators*	European	Eurostat

** See Annex A*

The data were collected and analysed for each grouping of subsectors (as set out in Table 4). Where more than one indicator within the same characteristic was deemed to be useful for a given grouping, those indicators were tested for correlation, using panel data methods (i.e. testing for correlation across all regions and time periods). If they were found to be correlated (and therefore the indices were effectively double-counting the same effect), they were either combined into one metric (as was the case for different modes of *freight movement* and *R&D expenditure* in different sectors) or one of the variables was removed (for example *SME birth rates* are included in preference to *SME survival rates*). As a result of this, each important criteria is represented by only one metric in the final analysis, and this allows us to combine the individual criteria scores to calculate a composite 'bioeconomy potential' index for each grouping of subsectors. In the special case of *upper secondary or tertiary education* and *quality of university*, there is evidence of correlation, based on the data and the understanding that regions with high-quality universities are likely retain more of their graduates. However, our aim is to use *upper secondary or tertiary education* as an indicator of the quality of workforce and *university quality* to reflect the *prominence of research institutes*, an important partner and source of spin-offs in bioeconomy. Where indicators have such a large scale that their indices create great distortions in the overall index score, a further transformation is required, as with the composite indicator of *infrastructure* due to the location of large ports in some regions. The clear exponential trend as shown in the plot of all data points suggest it is more appropriate to index these indicators from the natural logs rather than the original values (see Annex B for further details).

A number of indicators are identified as key for the existence of bioeconomy and therefore are included as an indicator of potential in all groupings. In particular, *domestic biomass production* (a proxy of biomass availability) is divided into four categories (agricultural biomass, marine biomass, forestry biomass & waste biomass) to demonstrate the availability of the appropriate type of biomass needed as inputs into the bioeconomy. For regions that do not produce sufficient biomass to supply other sectors, *transport of freight* measures their ability to import additional biomass from elsewhere and export the final products. Moreover, *SME birth rate* and *employment in Chemicals, polymers & biorefinery and Energy* are important factors leading to SME spin-offs, as are *R&D employment* and *quality of university*. The SME birth rate is represented by the business birth rate, as data suggests that over 99% of all businesses are SMEs. The co-existence of chemicals, polymers & biorefinery and energy sectors in the same region creates a strong foundation for the spin-off of bioeconomy companies, whereas university spin-offs are formed to commercialise the findings of successful research projects. The possibility and survival of these spin-offs can be enhanced by an already prominent sector with a large *share of total employment* and a favourable entrepreneurial culture involving a higher proportion of *small & micro businesses* and a greater degree of concentration (*density of firms*).

For all groups apart from primary biomass subsectors, availability of funding and quality of workforce are also used to demonstrate bioeconomy potential which is fostered by easy access to funding and/or a highly-educated workforce, especially in the case of high-cost subsectors such as chemicals and biotechnology.

Further description of indicators that are used to capture different aspects of each group of subsectors, along with any proxies, are outlined below.

5.1.1 Primary biomass sectors

The primary biomass grouping include five of the 16 subsectors (arable and livestock, horticulture, fishery, aquaculture and forestry/wood). There are four main indicators of potential and four indicators of current performance. The primary indicator of current performance are:

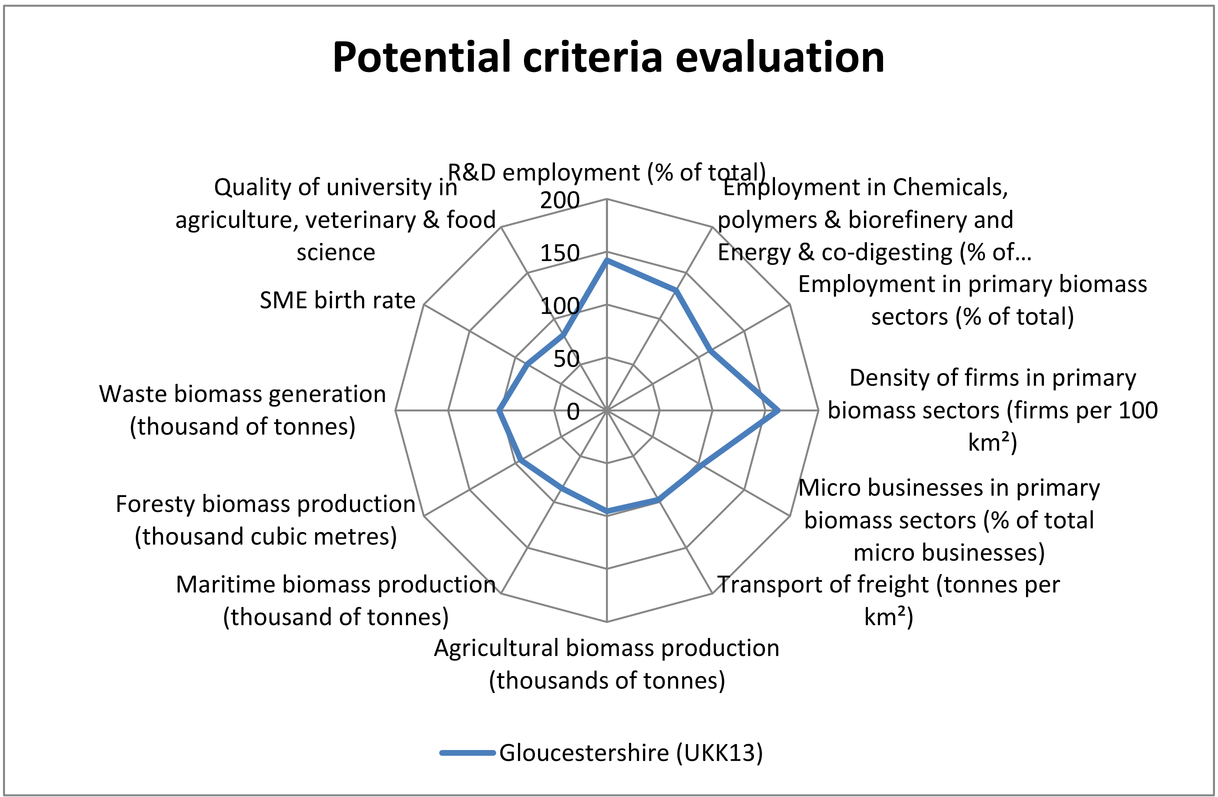
- shares of employment and
- firms in primary biomass sectors (important);
- shares of employment and
- firms in bioeconomy subsectors (slightly important)

The shares of employment and firms indicators show the scale of the sectors in the economy as well as whether they are made up of many small firms or a few large firms.

Biomass domestic production comes in the form of inputs such as fertilisers and animal feeds and is separated into four biomass categories: agricultural biomass, marine biomass, forestry biomass and waste biomass. Other important indicators of potential are economic criteria. The *share of primary biomass sector employment in total employment* indicates public approval of agricultural activities taking place and the significance (or contribution) of the sector in the region. *Density of firms* is measured as the number of firms in primary biomass sectors per 100 km², and is used as a proxy for cluster size and *shares of small and micro businesses* (those employing less than 10 people) is used to enhance the entrepreneurial culture of the region.

An example of a region highly ranked on the overall potential for primary biomass sectors is **Gloucestershire** where there are more people employed in R&D and Chemicals, polymers & biorefinery and Energy than the average NUTS3 region. There is also a high density of firms in primary biomass sectors (see Figure 2).

Figure 2 Primary biomass potential in Gloucestershire



Suffolk in East Anglia also performs well in terms of both potential and current performance. Not only does the region produces more biomass and employs more people in agriculture but it also has strong infrastructure to transport biomass, thanks to the port of Felixstowe[9] located in the county. The high proportion of employment in R&D and Chemicals, polymers & biorefinery and Energy, along with the densely populated business demography set a strong foundation for spin-offs. In addition, the proportions of employees and firms in the primary biomass sectors are also high compared to the UK (see Figures 3 and 4).

Figure 3 Current status of Primary biomass sectors in Suffolk

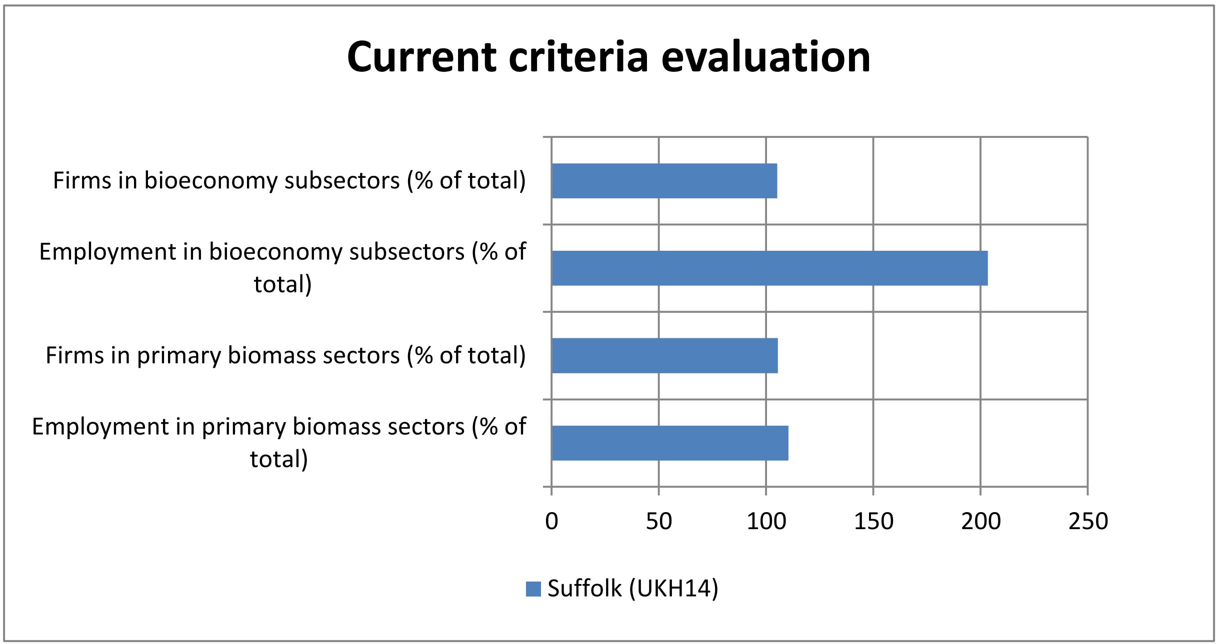
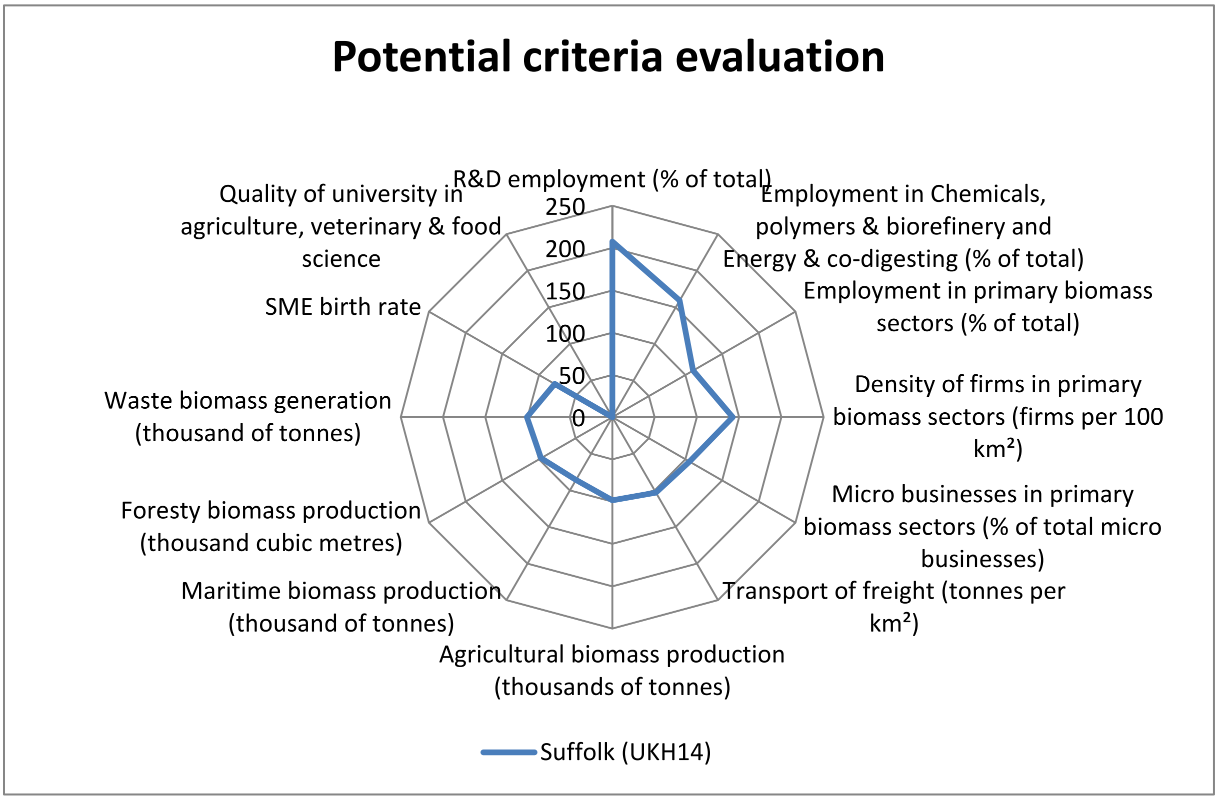
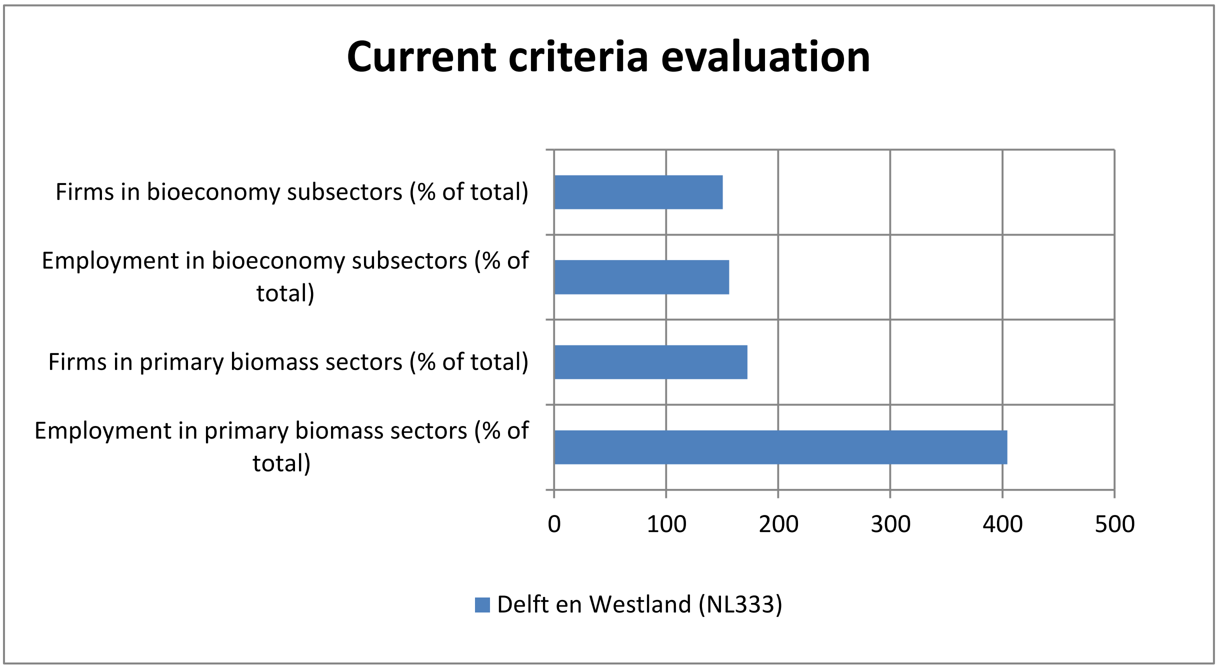


Figure 4 Primary biomass potential in Suffolk



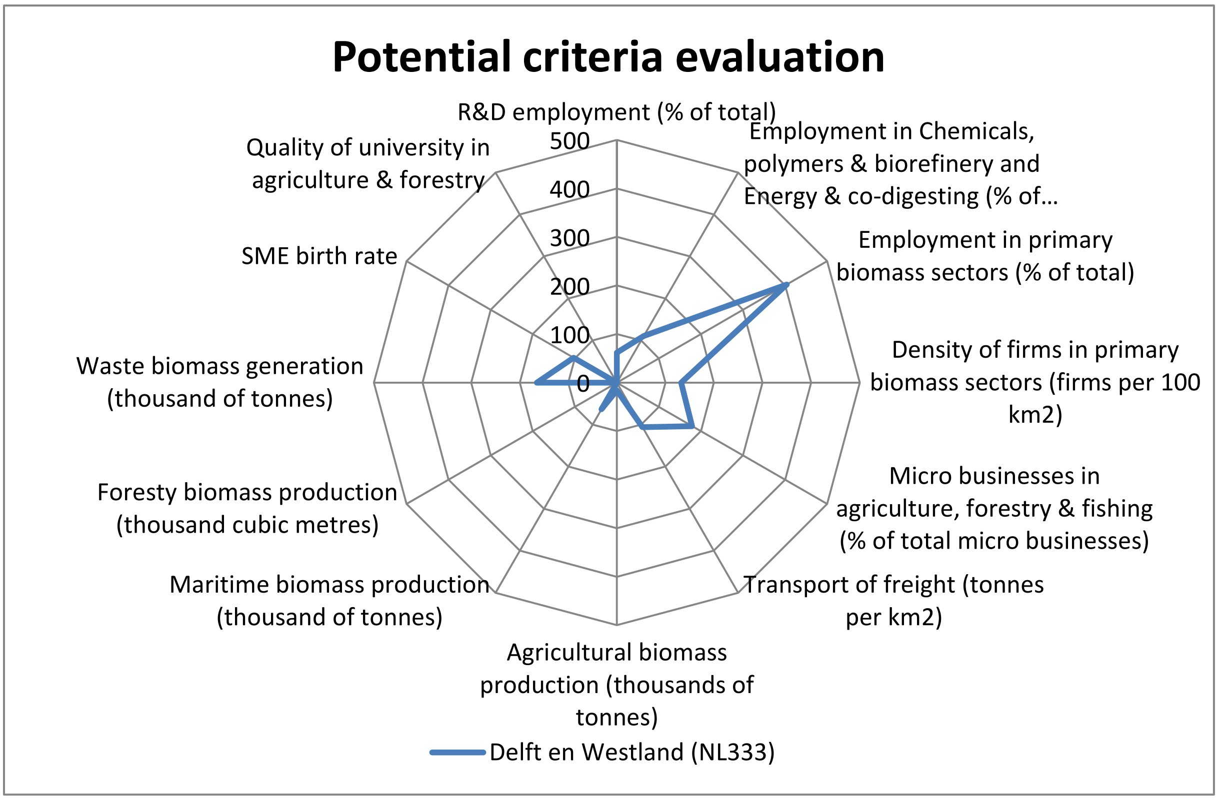
9 http://www.portoffelixstowe.co.uk/

Figure 5 Current status in Primary biomass sectors in Delft and Westland



In the Netherlands, a region with great potential in primary biomass sectors is **Delft and Westland** which exceeds the national average in all indicators of current status. The employment share of agriculture in this region is particularly high. It also produces significantly more biomass (total of all categories) than the Netherlands as a whole, which may be due to the specialisation in greenhouse horticulture and intensive production, a large share of micro businesses and good transport links (see Figures 5 and 6).

Figure 6 Primary biomass potential in Delft and Westland

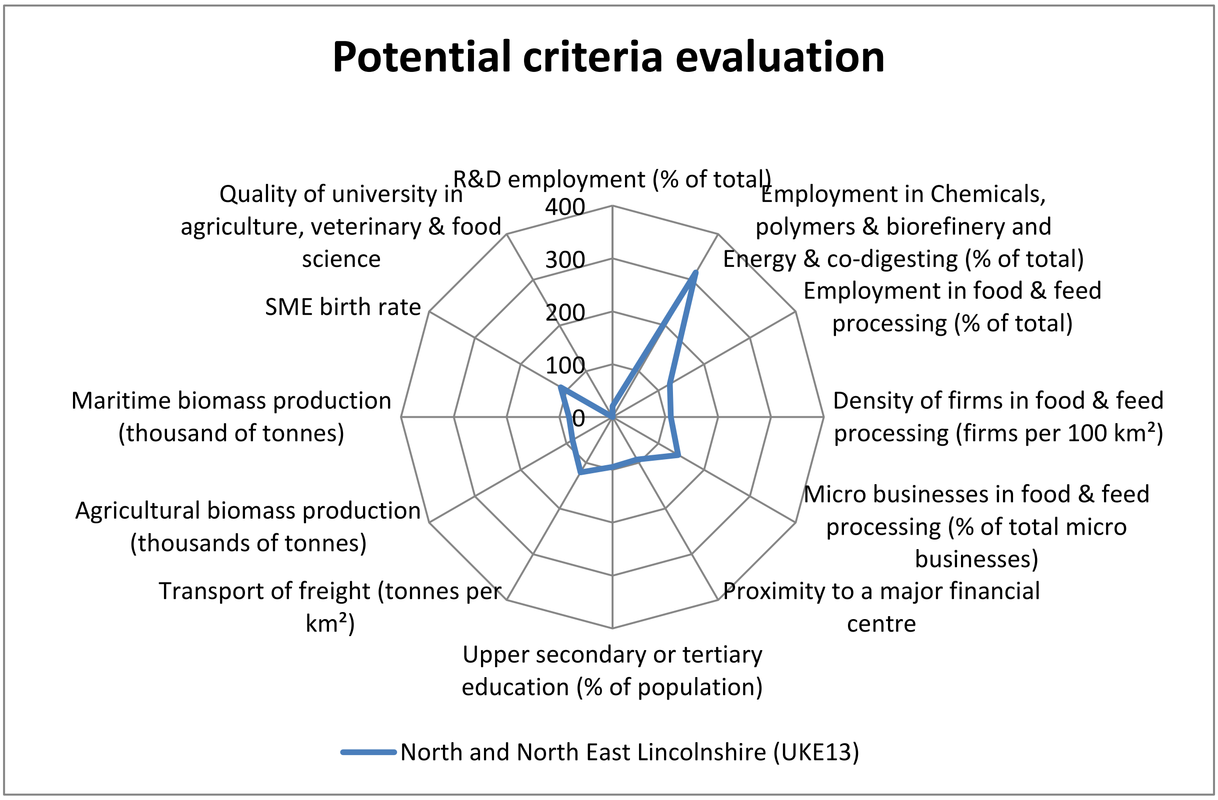


5.1.2 Food & feed processing

Similarly to primary biomass sectors, indicators of current performance for food & feed processing are also the *shares of employment* and *firms* in these subsectors and in all bioeconomy subsectors. To explore biomass potential, we have used *production of agricultural and marine biomass* as indicators of biomass availability, as the food & feed processing sector has intermediate demand for output from these categories other than forestry and waste.

North and North East Lincolnshire is one of the regions with active food & feed processing sectors where the shares of employment and firms are much higher than the UK average. The region also employs more people in the chemicals and energy sector and has significantly more micro businesses than the UK as a whole. Locally produced biomass serves as inputs into the sector as it is located in Lincolnshire where primary biomass sectors are strong. The potential for developments in food & feed processing also lies in the high SME birth rate and especially the two ports of Immingham and Grimsby which together handles the largest tonnage of freight in the UK (see Figure 7).

Figure 7 Food & feed processing potential in North and North East Lincolnshire



Falkirk in Scotland also has a similarly high score, especially in the share of employment in chemicals & energy sectors, the density of businesses in food & feed processing and the proximity to Edinburgh (see Figure 8).

The current status of food & feed processing in many regions in the Netherlands is broadly comparable to or only slightly more developed than the national average but a number of regions have significantly more potential. One example is **Zaanstreek** with a larger food and feed processing sector and a higher density of food & feed processing firms, compared to the Netherlands and proximity to Amsterdam (see Figure 9).

Figure 8 Food & feed processing potential in Falkirk

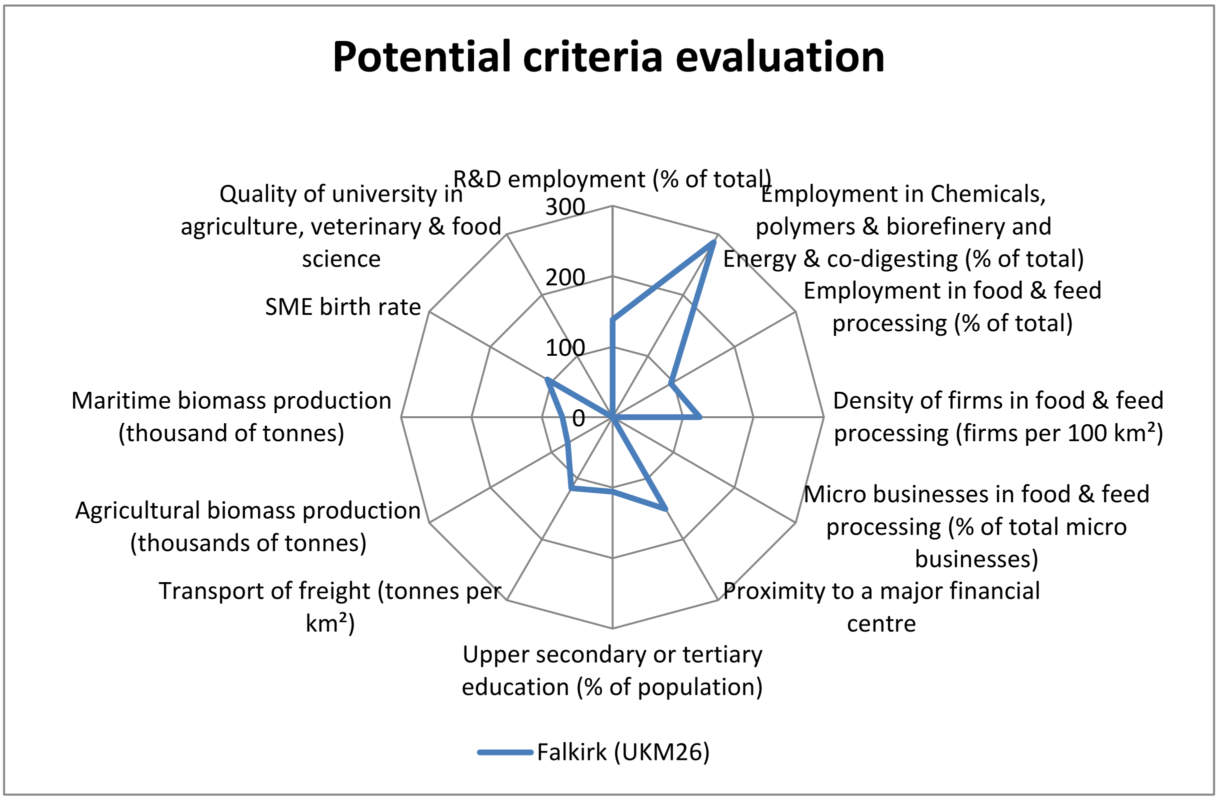
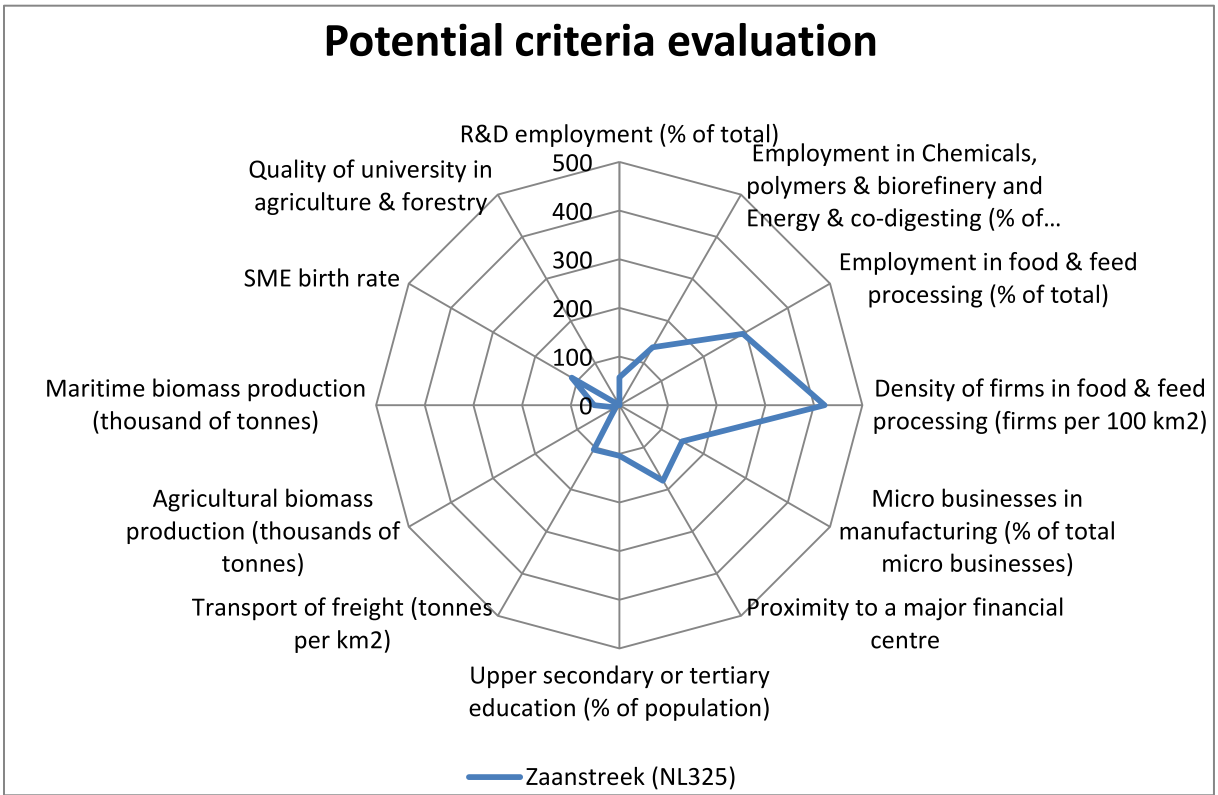


Figure 9 Food & feed processing potential in Zaanstreek



5.1.3 Construction

We have defined the construction sector as a producer of bio-based building materials rather than building activities themselves. For this reason, indicators of biomass production cover the agricultural and forestry biomass categories. In terms of current performance, the share of employment and firms are used to reflect the size and activeness of construction and all bioeconomy subsectors.

For instance, **Kent CC** performs relatively well compared to the UK as a whole on almost all indicators (see Figure 10). It has a higher potential index thanks to easy access to London, the high proportion of micro businesses and the high density of firms in construction outperforming by the UK by 3½ times. The current sector also has a high share of employment and firms compared to other regions.

Figure 10 Construction potential in Kent CC

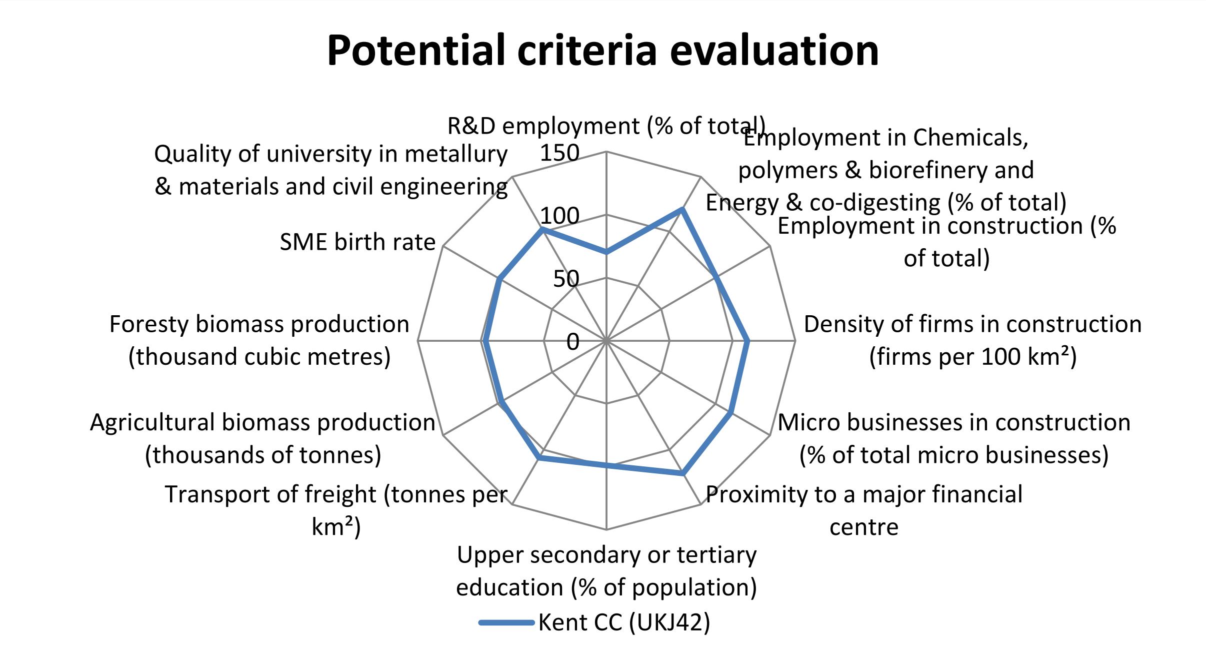
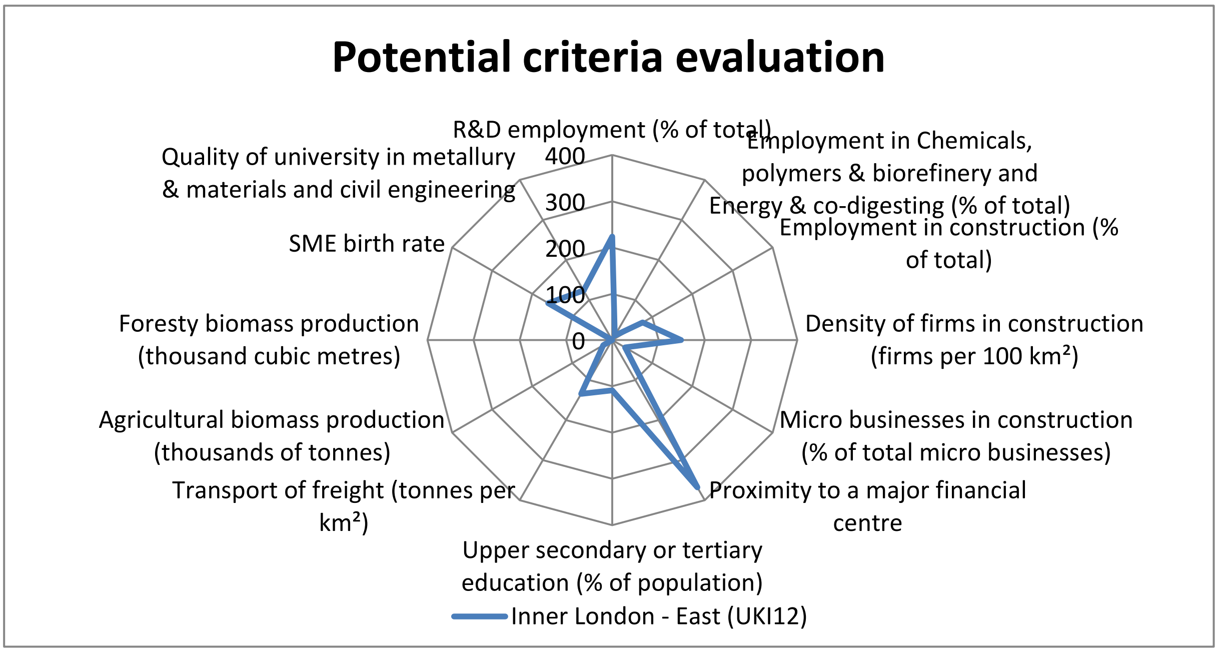


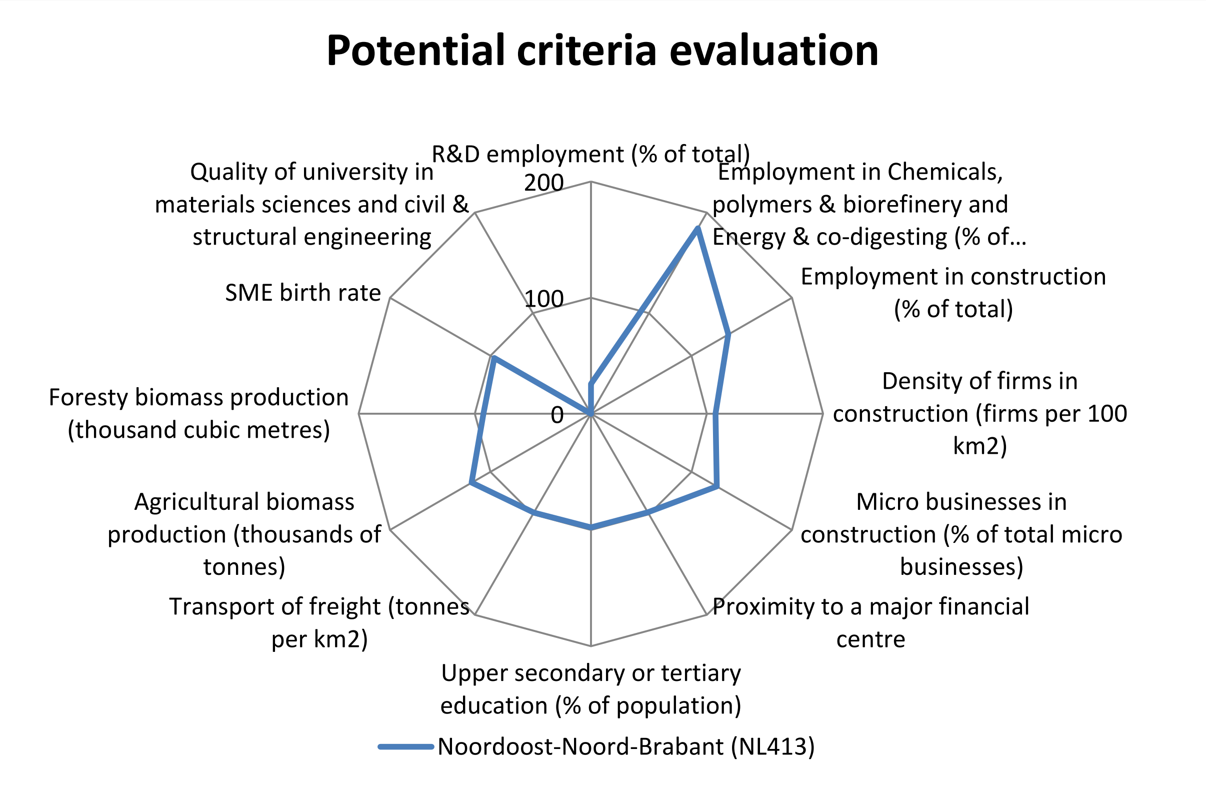
Figure 11 Construction potential in Inner London - East



On the other hand, **Inner London - East** is an example of a region where the sector is not yet established but has the potential to become prominent. Its index scores exceed the UK average in most indicators of potential (see Figure 11). Situated in the capital, it is understandable that the region has strong transport links, a high SME birth rate and a corresponding high share of employment and density of firms in construction to meet the demand for both offices and housing. Additionally, universities also provide high quality research and graduates in metallurgy & materials and civil engineering to support the sector.

None of the regions of the Netherlands has a potential index larger than 100, but **Noordoost-Noord Brabant** is a Dutch region with the most future potential in construction also developed. The main driver of potential is agricultural biomass production, employment in chemicals & energy sectors and the high density of firms in construction (see Figure 12).

Figure 12 Construction potential in Noordoost-Noord-Brabant



5.1.4 Chemicals, polymers and biorefinery

Besides the standard indicators of current performance including *shares of employment and firms*, an additional indicator, *extra-EU exports of chemicals and related products as a percentage of total GVA* is also included. The reason is that many countries produce chemicals, pharmaceuticals and similar products for export, rather than to supply only domestic demand. Exports to outside the EU can be an illustration of demand as well as specialisation in this group of subsectors. However, the lack of data means that this indicator is excluded from the analysis for the Netherlands.

Due to the R&D intensive and high-cost nature of these subsectors, R&D employment and availability of funding are especially important for their development. For the same reason, these subsectors need a skilled workforce, quality research facilities and links with universities or research institutes. The percentage of the population with upper secondary or tertiary education and quality of university are suitable for such criteria. Raw inputs into the chemicals, polymers & biorefinery subsectors often come in the form of agricultural, forestry or marine biomass which area included as indicators of biomass availability.

Cambridgeshire has been established as a centre of development for chemicals and pharmaceuticals companies. The short distance to London and Cambridge University play an important role in the development of business clusters in Cambridge, providing solutions to high costs and the need for a high quality workforce and research institutions. The region is also well known for the clusters of chemicals & pharmaceuticals companies in Cambridge. These are the reasons for the high share of employment and firms in these sectors and exports of chemicals and related products and the potential for further developments in these sectors (see Figures 13 and 14).

Figure 13 Current status of Chemicals, polymers & biorefinery in Cambridgeshire

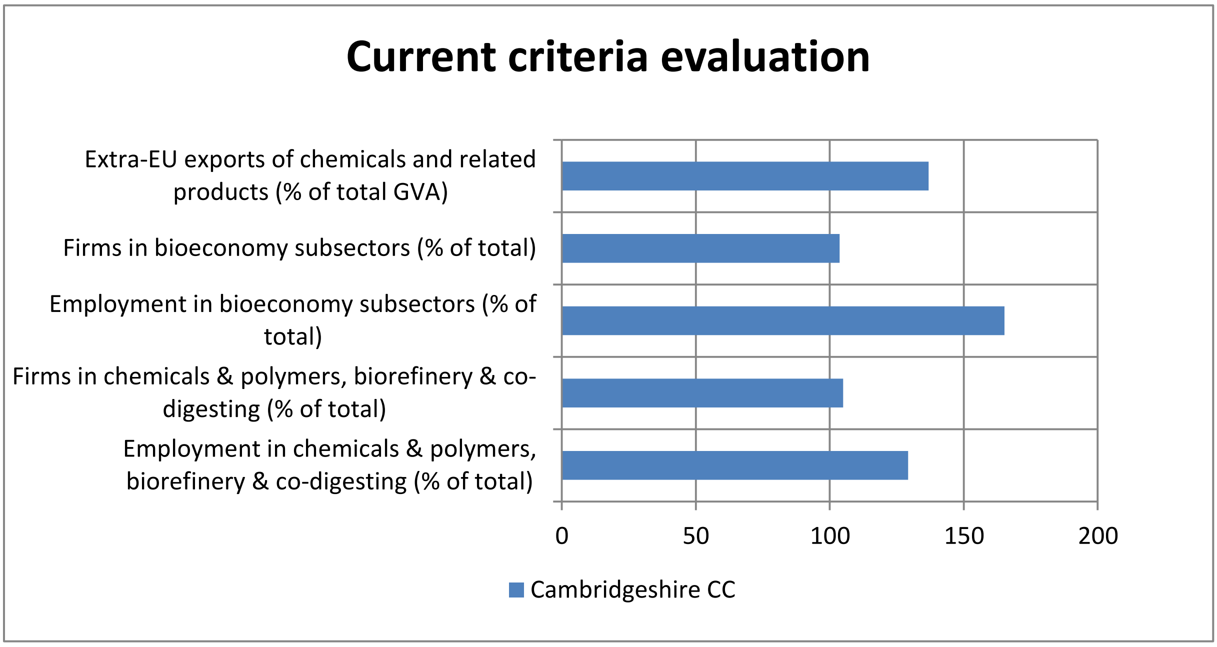
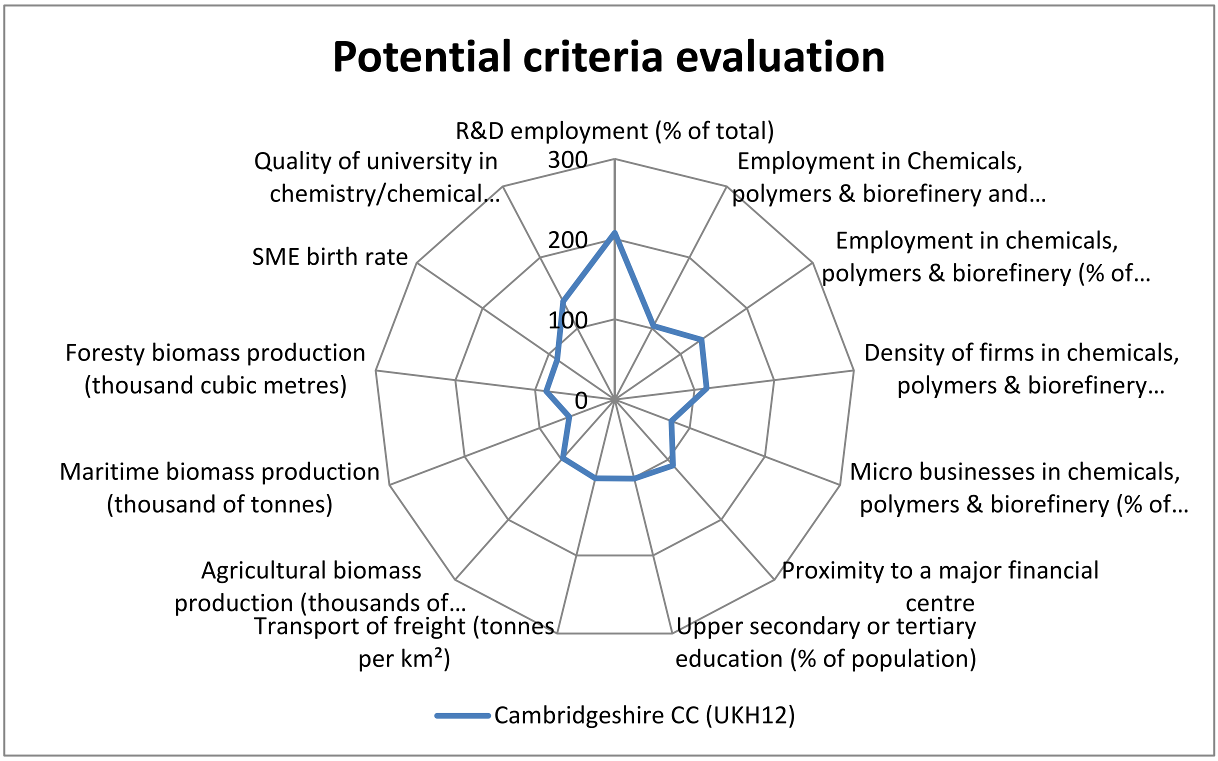


Figure 14 Chemicals, polymers & biorefinery potential in Cambridgeshire



Also situated in East Anglia, **Norfolk** scores highly across most potential indices (see Figure 15). Situated closely to London, It not only shares similar characteristics with Cambridgeshire such as a high share of R&D employment and a high density of firms in chemicals, polymers & biorefinery but also stands out for the high level of production of all biomass categories.

Figure 15 Chemicals, polymers & biorefinery potential in Norfolk

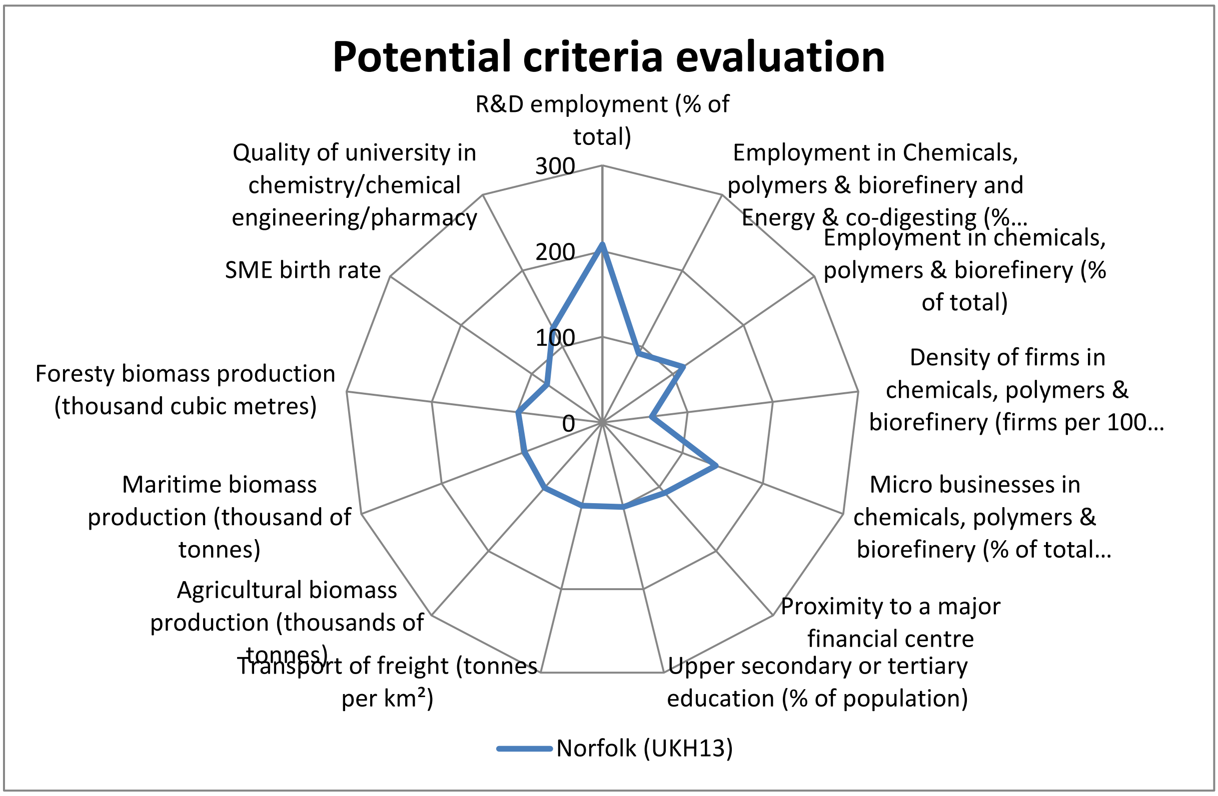
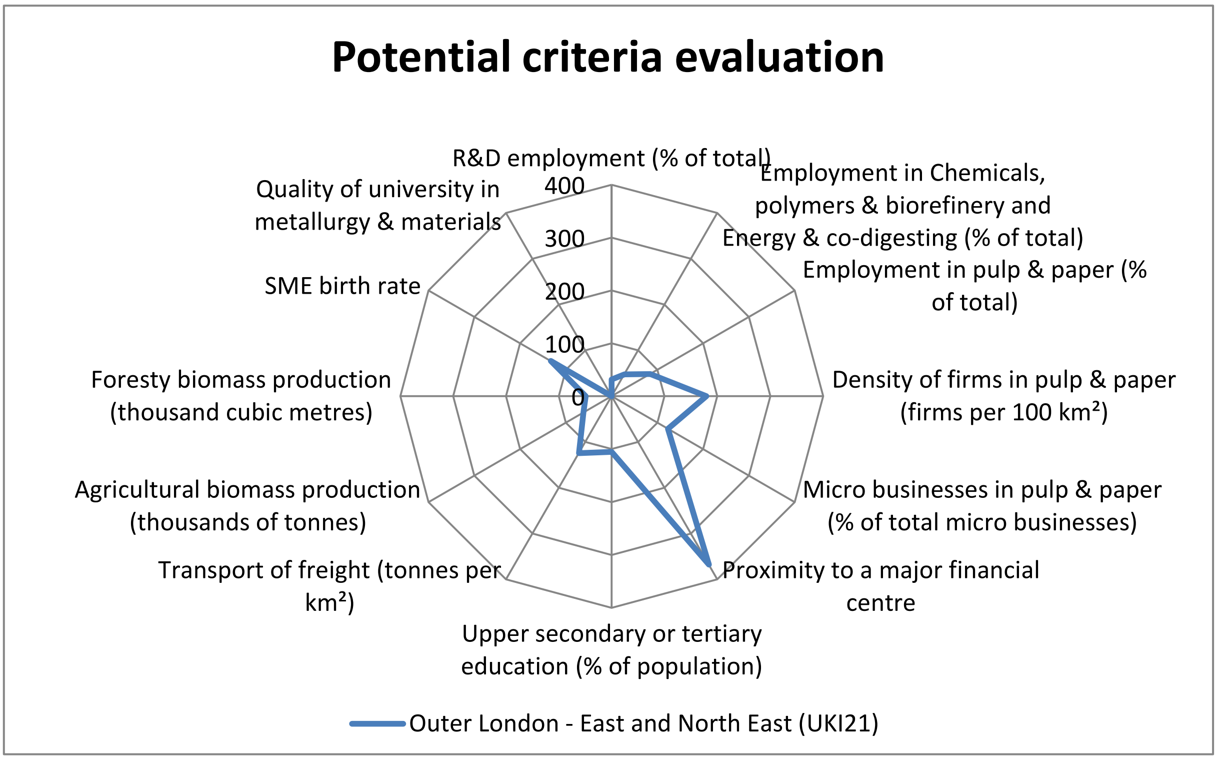
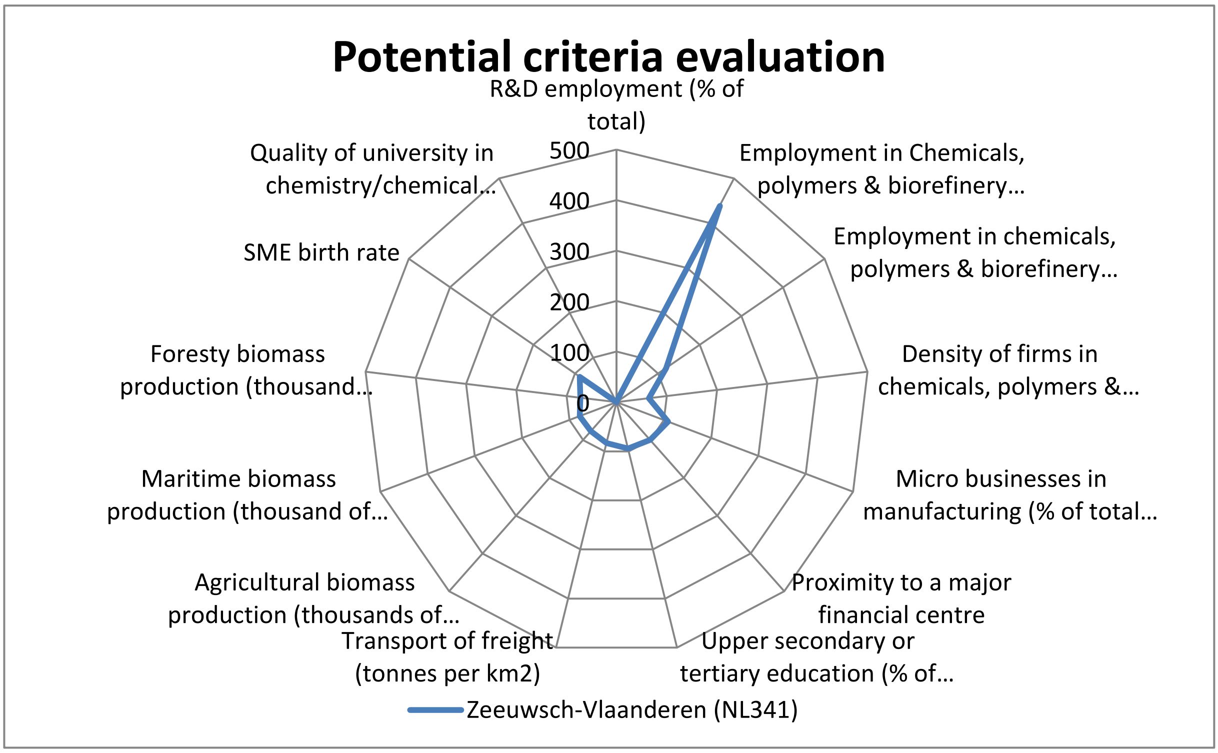


Figure 16 Pulp & paper potential in Outer London – East & North East



Zeeuwsch-Vlaanderen is the only region in the Netherlands which has the potential for the chemicals, polymers & biorefinery sector, thanks to the strikingly high share of employment in chemicals and energy sectors (see Figure 17). The indices of the share of micro businesses, proximity to a financial centre and proportion of the population with upper secondary or tertiary education are in line with the national average.

Figure 17 Chemicals, polymers & biorefinery potential in Zeeuwsch-Vlaanderen



5.1.5 Pulp & paper

Inputs into the production of pulp & paper are either raw materials, namely wood, or processed materials which can then be used to make paper and paper products; both can be produced locally or imported from elsewhere. To encounter for all possibilities, we include in the list of indicators for potential *forestry biomass production*, a proxy for biomass availability and *transport of freight*, a measure of infrastructure. The current status is demonstrated by the shares of employment and firms in pulp & paper and in all bieconomy subsectors.

The majority of regions with potential for the pulp & paper sector are in the surrounding regions of London. For example, **Outer London – East & North East**'s indices in *density of firms and share of micro businesses in pulp & paper, SME birth rate* and *transport of freight* all exceed the UK average (see Figure 18). One of the few regions outside the London area that outperforms the UK in this sector is **Greater Manchester South**. Despite underscoring on biomass production and SME birth rate, the region has good infrastructure, a pronounced university, a high score in employment in chemicals and energy sectors, as well as density of firms and share of micro businesses (see Figure 19).

Figure 18 Pulp & paper potential in Outer London – East & North East

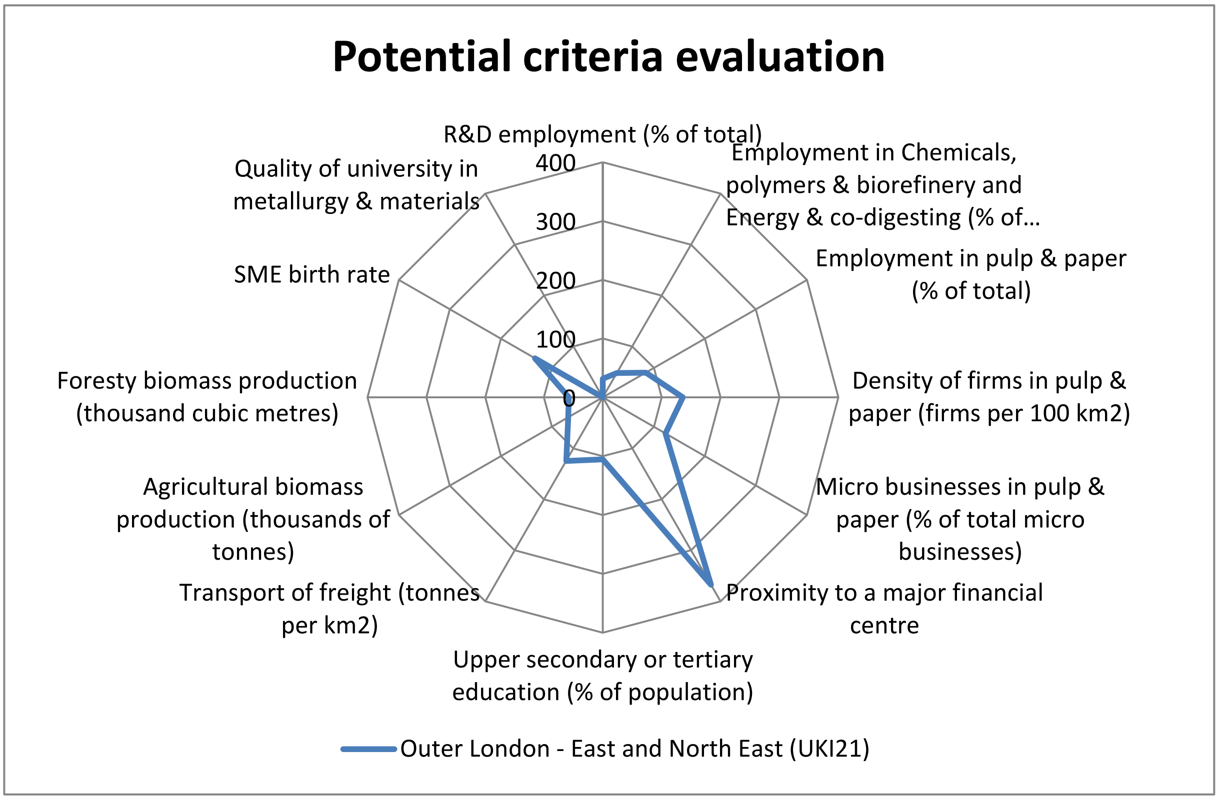
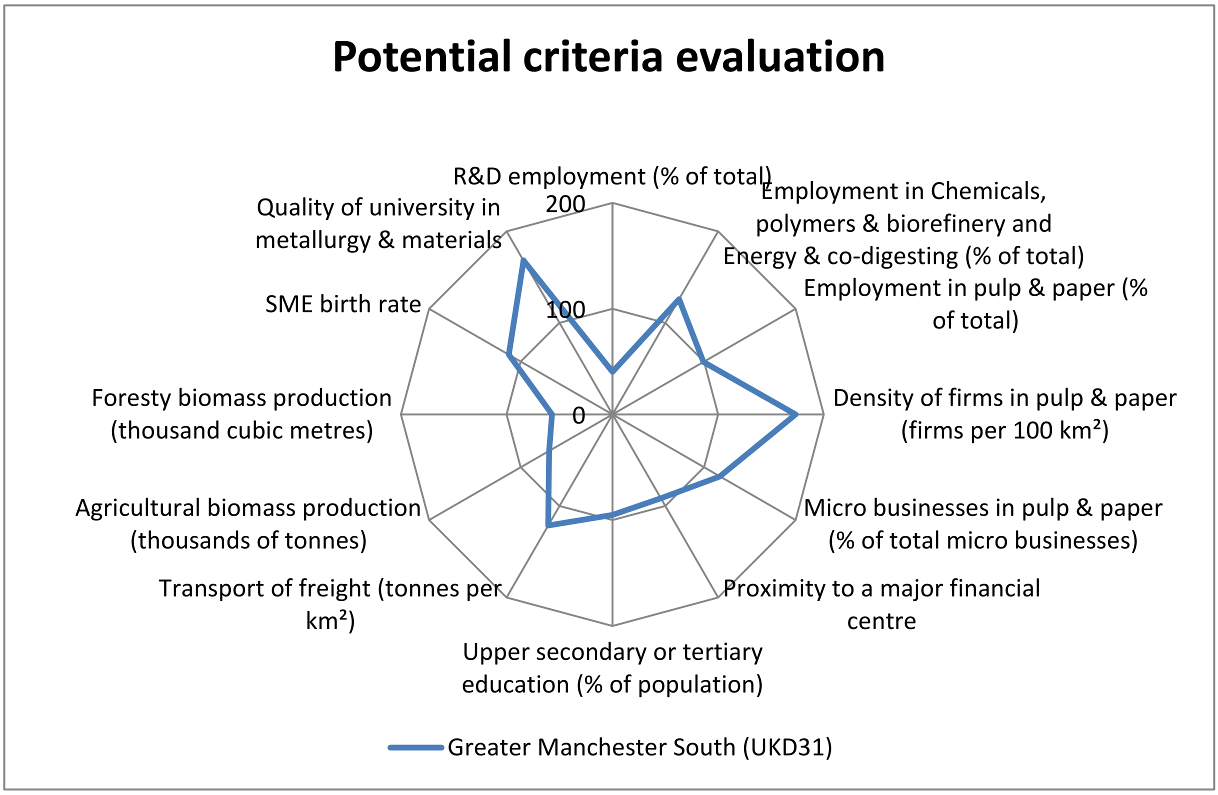


Figure 19 Pulp & paper potential in Greater Manchester South



In the Netherlands, **Achterhoek** has a well-established pulp & paper sector with the share of employment and firms in pulp & paper being three times the national average (see Figure 20). In terms of potential, the region also outperforms all other regions except one. Unlike in the UK, indices of potential in the Netherlands and in Noord-Limburg in particular are driven by employment in pulp & paper and biomass production (see Figure 21).

Figure 20 Current status of Pulp & paper in Achterhoek

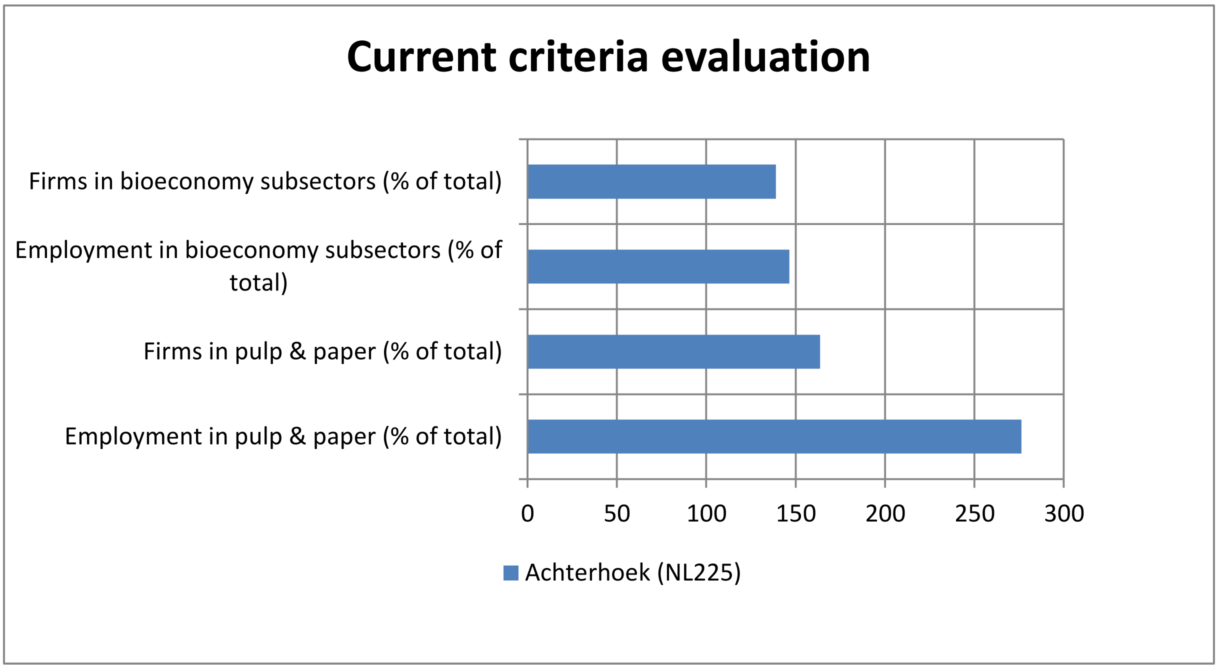
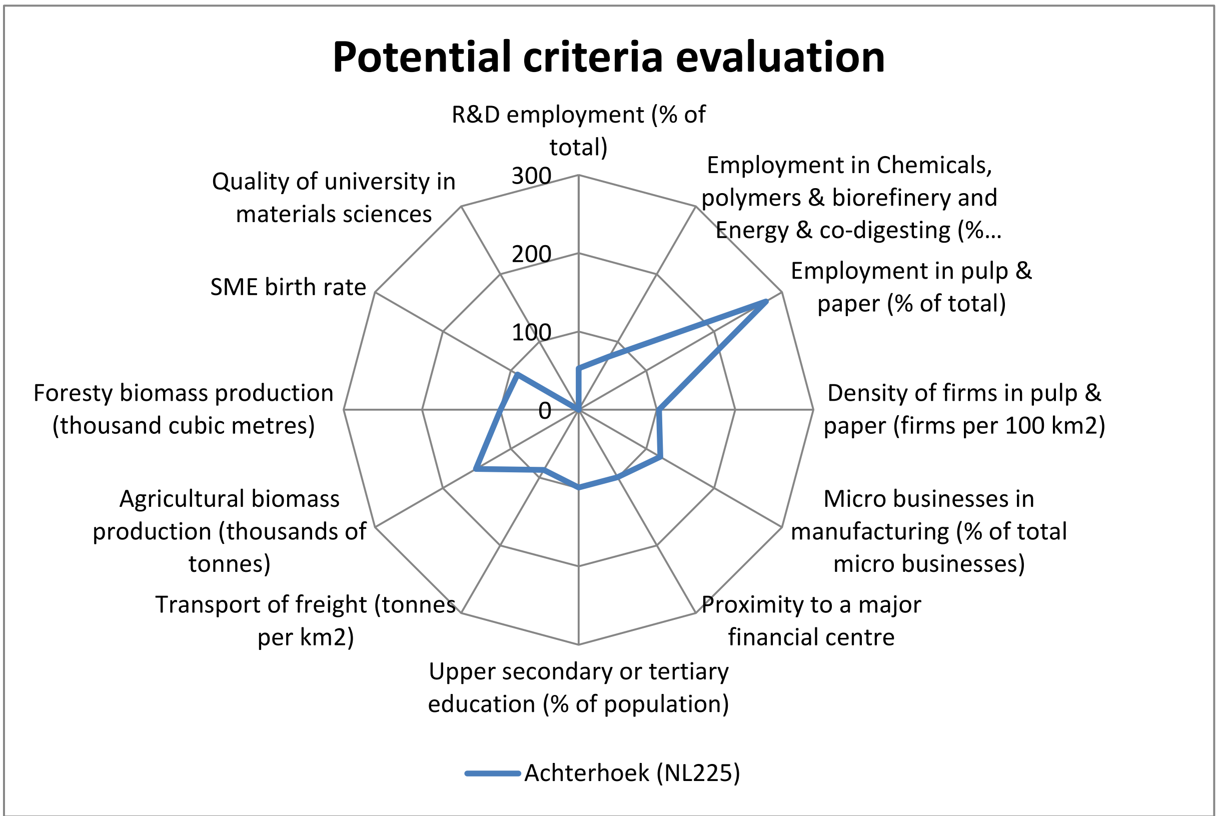


Figure 21 Pulp & paper potential in Achterhoek



5.1.6 Textiles & clothing

For textiles & clothing, indicators of current performance are equivalent to those used for food & feed processing. Potential of bioeconomy in this subsector revolves around *infrastructure, economic history* and *rate of SME formation*. Because the majority of regions do not grow crops or keep animals for fibres, they need to import raw materials from outside the region. Therefore *transport of freight density* is an especially important indicator for this group of subsectors. *Agricultural biomass production* is however still included to account for regions that specialise in fibre crops.

The overall index in this sector is dominated by the employment and business indices. Leicester's index of *employment in chemicals and energy sectors* is twice as large as the UK average; its indices of employment and firms, density of firms and share of micro businesses in textiles & clothing, the subsector with bioeconomy potential, are also high (see Figures 22 and 23). The region also performs well in other indicators of potential, in particular *infrastructure* and *SME birth rate*. Leicester has historically been associated with the textiles industry and has the sites of many shoes & clothing retailers such as Jessops, Next and Shoe Zone.

Figure 22 Current status of Textiles & clothing in Leicester

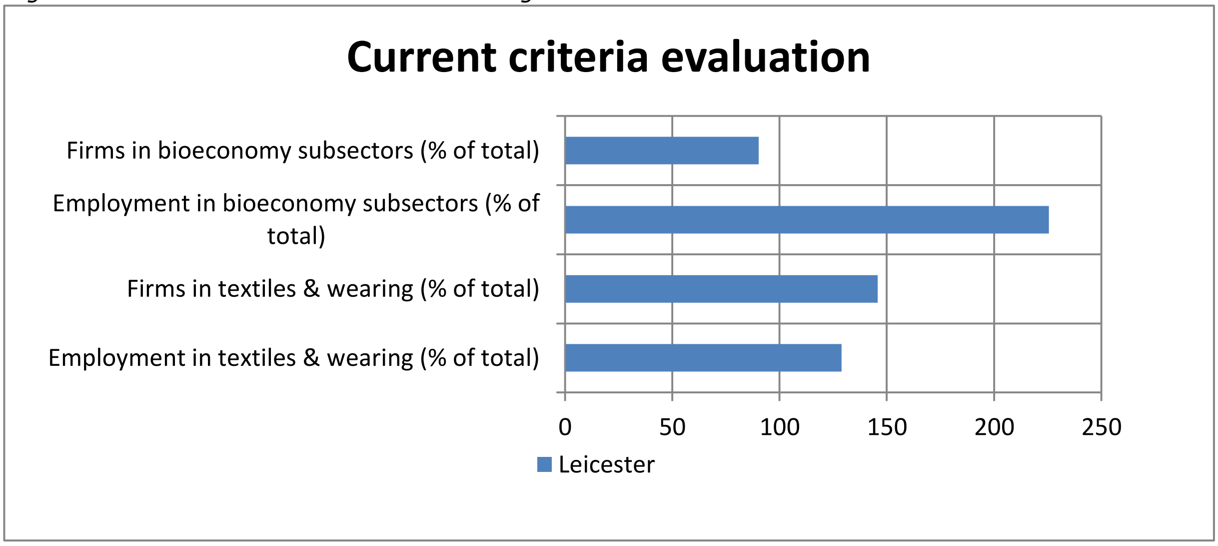


Figure 23 Textiles & clothing potential in Leicester

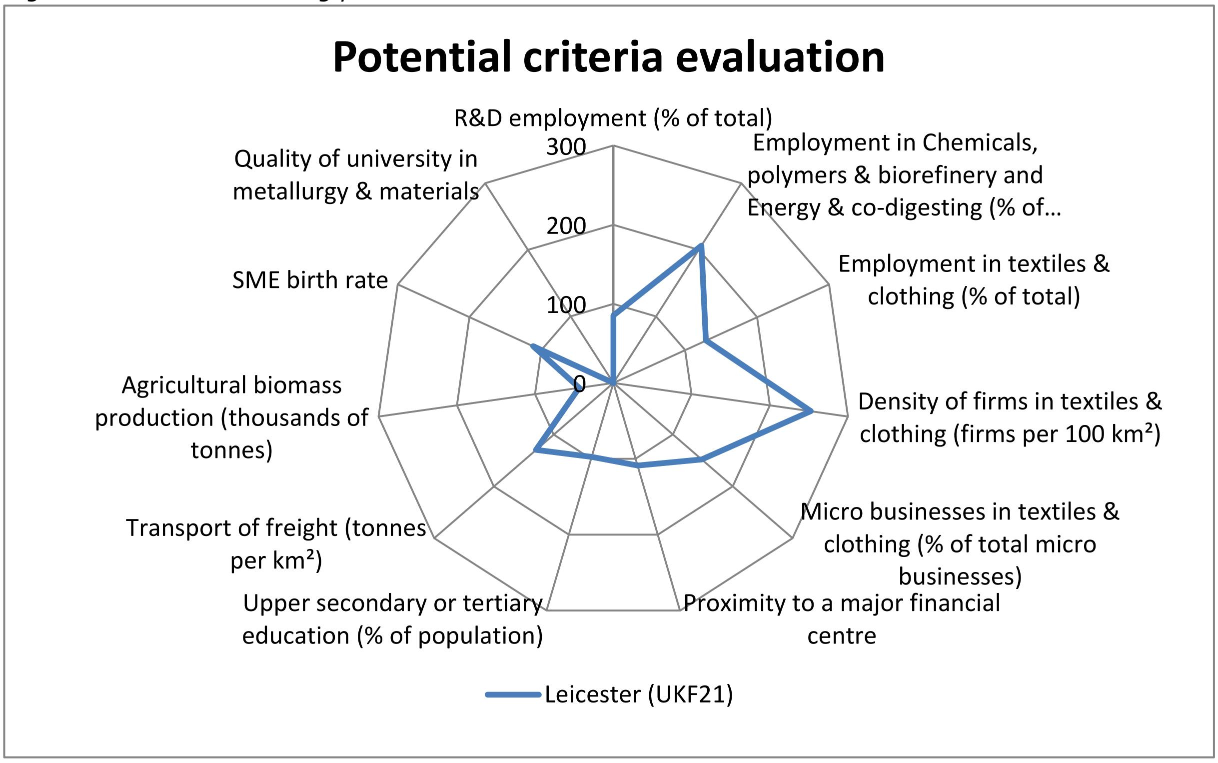
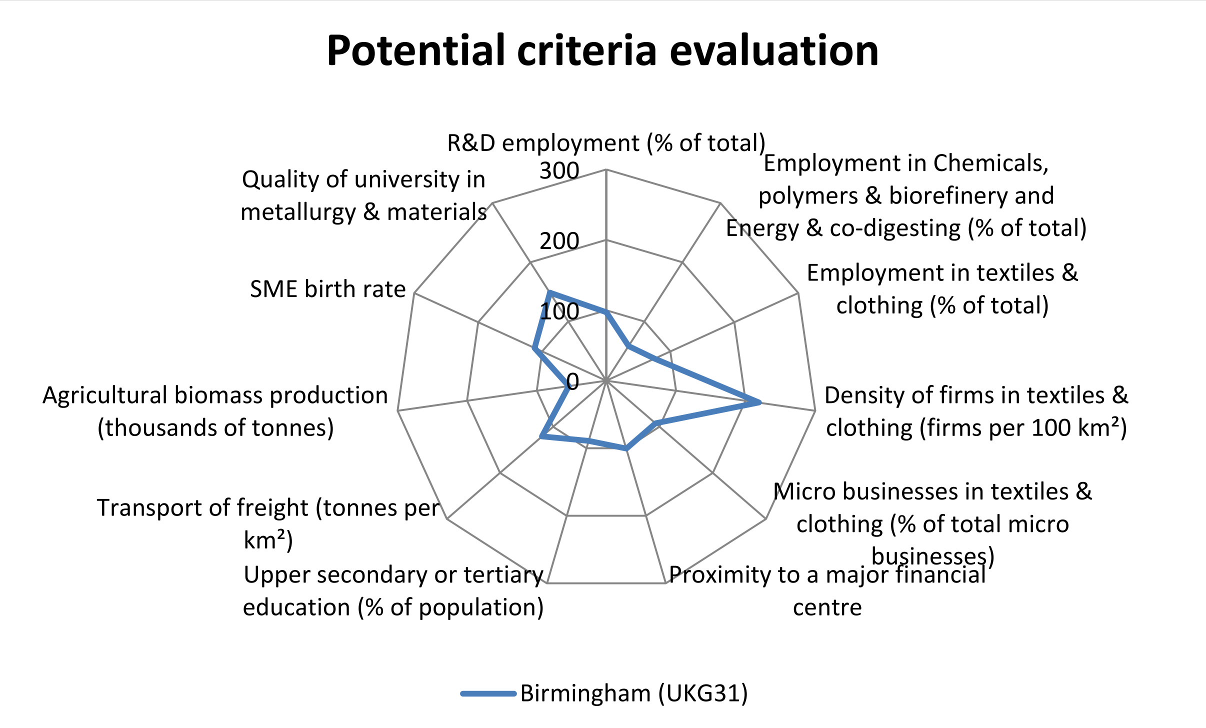
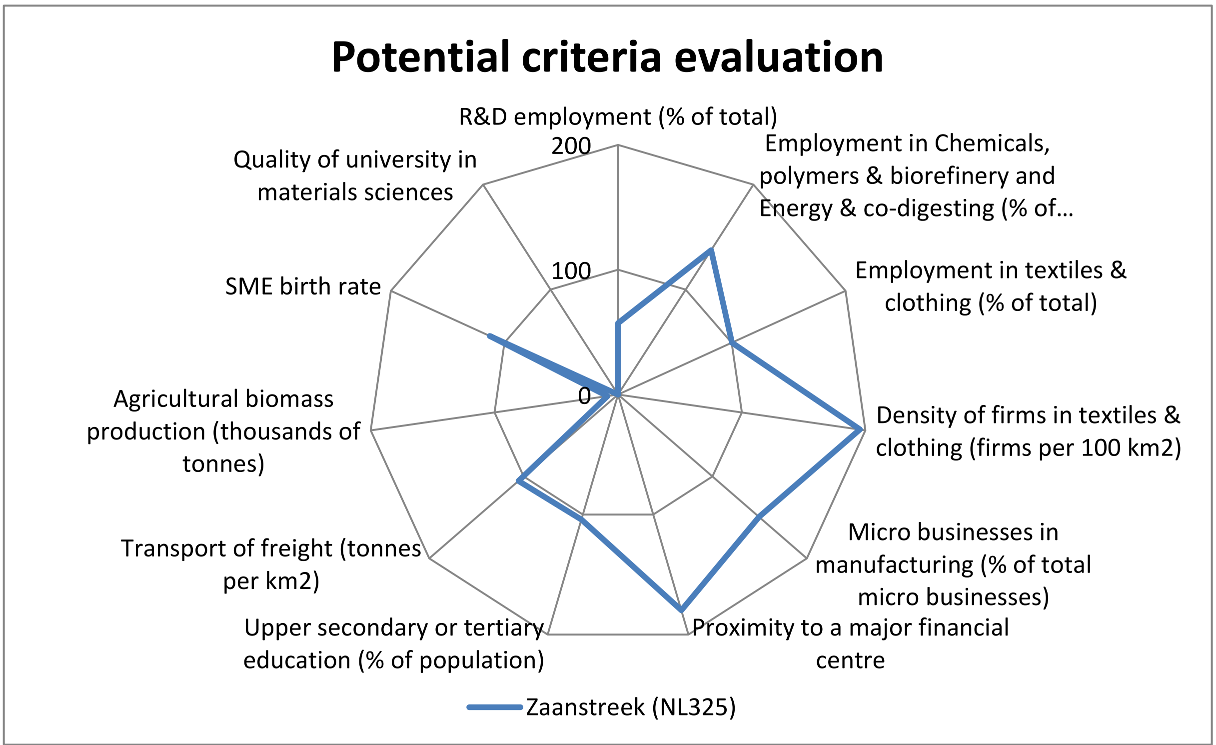


Figure 24 Textiles & clothing potential in Birmingham



Meanwhile, **Birmingham** scores highly compared to the UK in SME birth rate, quality of university in metallurgy & materials and density of firms in textiles & clothing (see Figure 24) and **Zaanstreek** outperforms the Netherlands's average in terms of both current performance and potential (see Figure 25).

Figure 25 Textiles & clothing potential in Zaanstreek



5.1.7 Energy

Being a relatively new sector, energy has a larger number of indicators of future potential than for current status. The indicators of current performance are *shares of employment and firms in energy and in all bioeconomy subsectors*. Indicators of future potential in the energy sector are similar to those in chemicals, polymers & biorefinery because they both rely on research and development, large investments and skilled workers. *Proximity to a major financial centre*, *upper secondary or tertiary education* and *quality of university in energy-related subjects* are chosen for these criteria. *Forestry, marine and waste biomass production* are used as indicators of biomass availability because the nature of the energy subsector allows it to utilise different types of biomass, more than any other grouping using biomass as inputs. Plant-based waste has especially become a popular source of green energy, as opposed to fossil fuel and solid wood.

Not many regions have a major energy sector but there are some which stand out with the potential to develop one. **Oxfordshire** is a region with a relatively large share of employment in energy that when combined with employment in chemicals, polymers & biorefinery becomes even larger. It also outperforms the UK as a whole in the density of firms in energy, R&D employment and quality of university (see Figures 26 and 27).

Figure 26 Current status of Energy in Oxfordshire

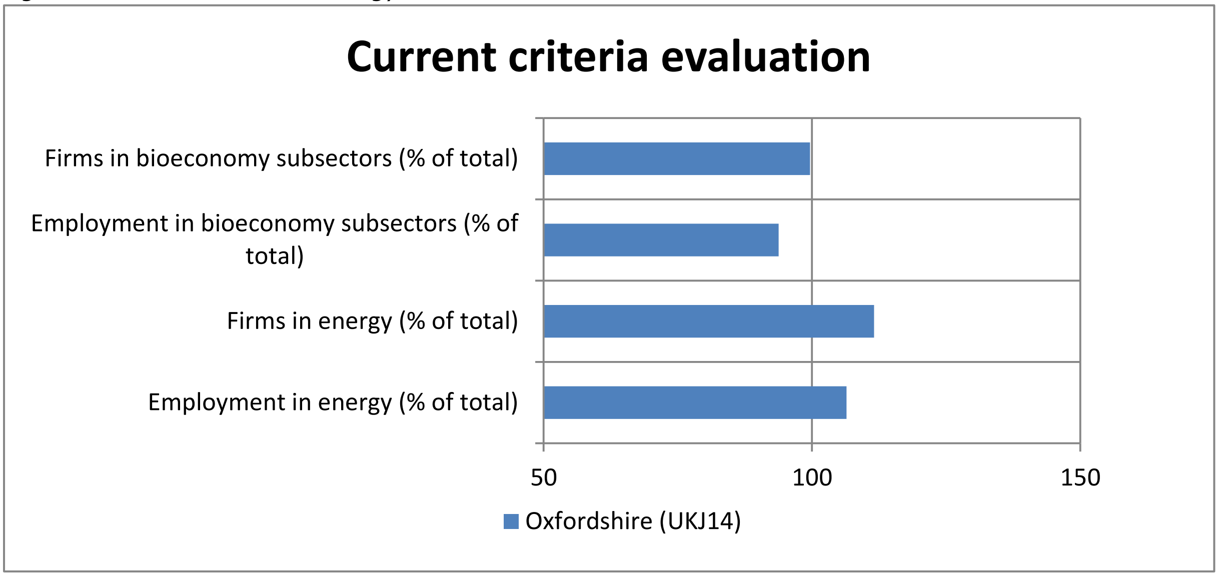
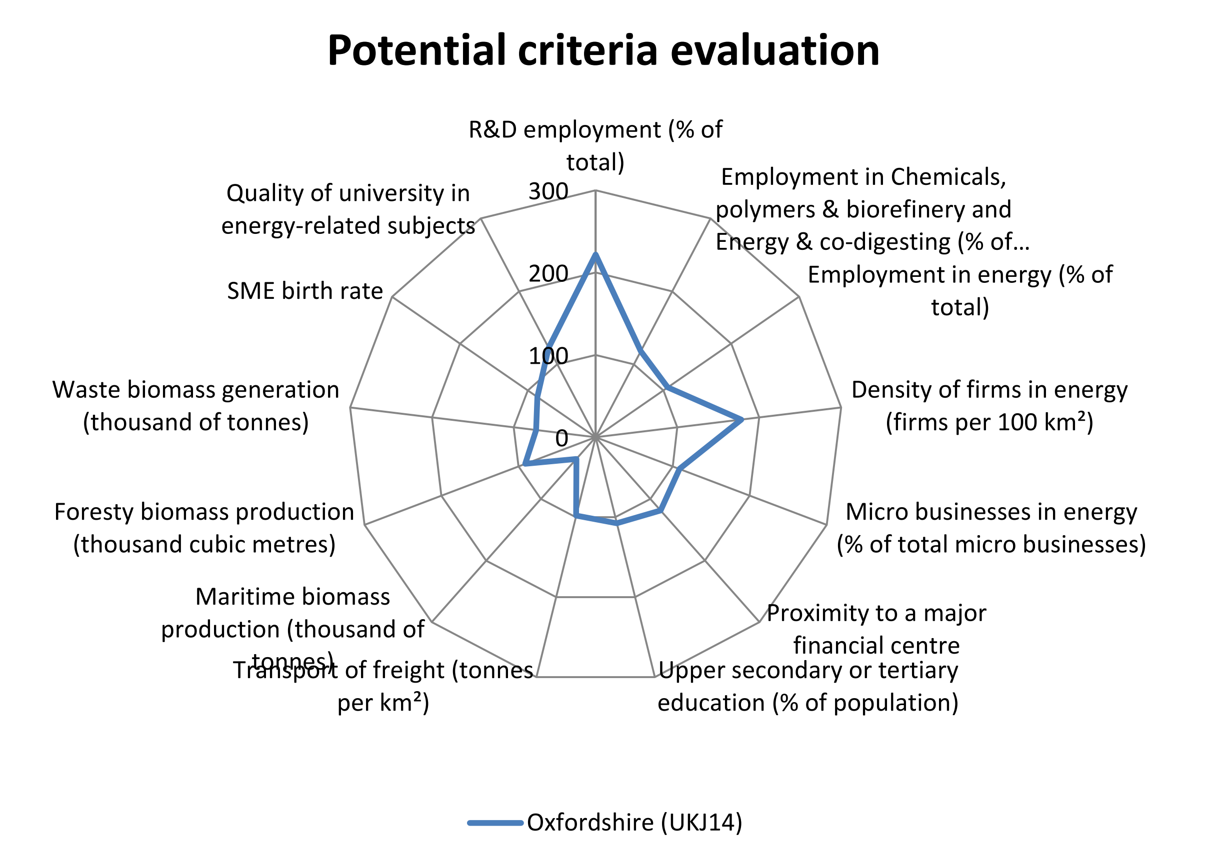
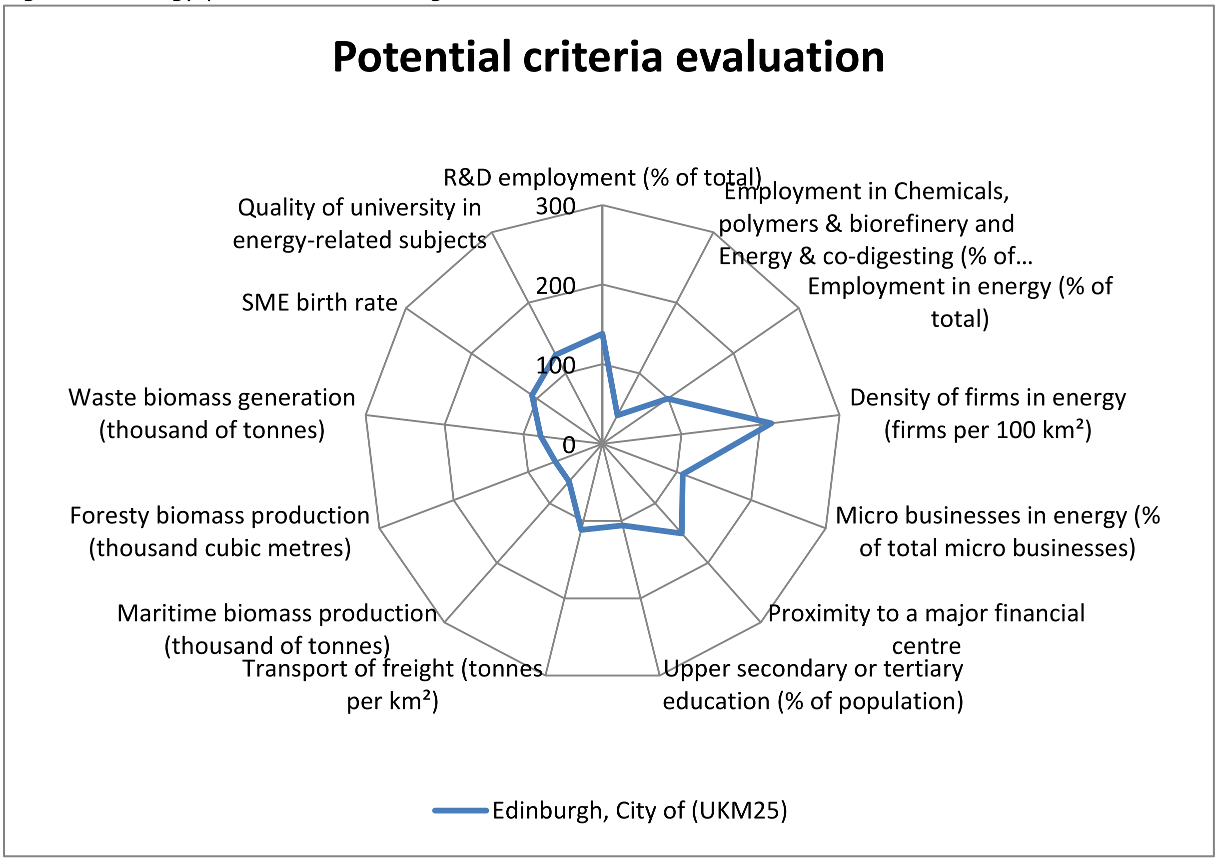


Figure 27 Energy potential in Oxfordshire



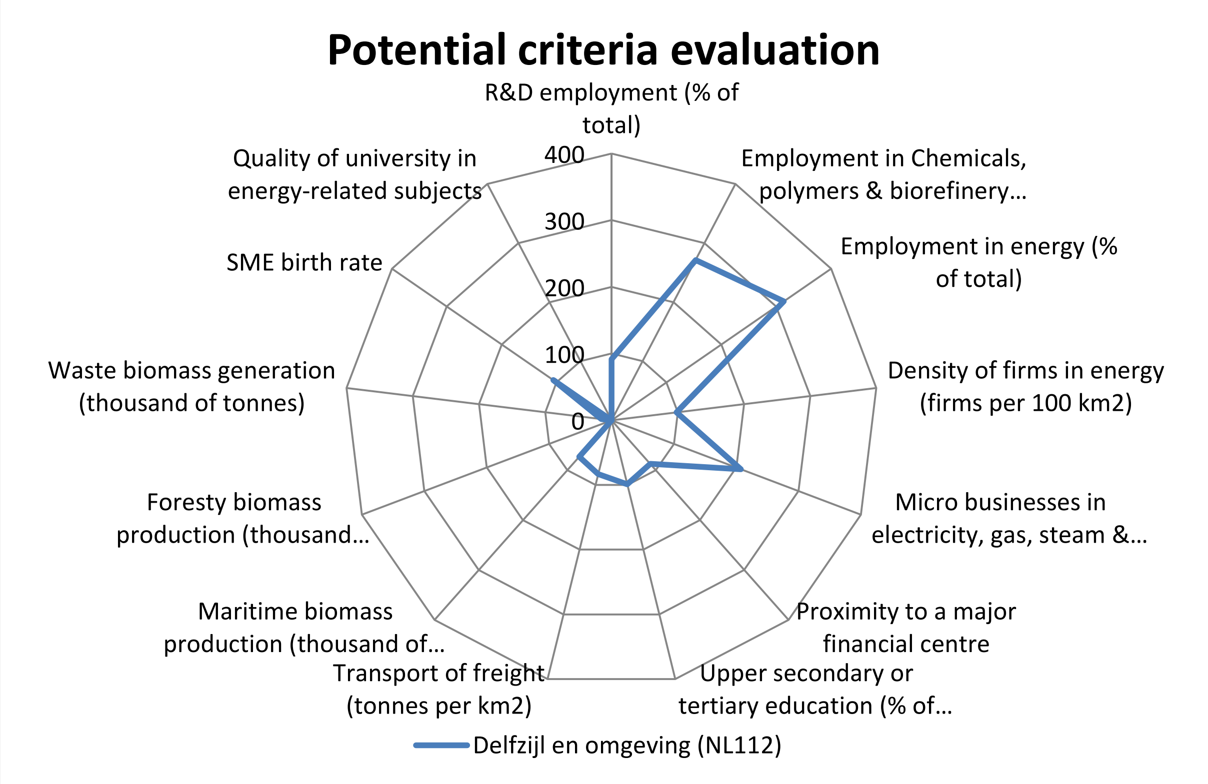
Edinburgh has a similarly high overall score; the potential for the energy sector is driven by similar factors to a different extent. The *share of employment in R&D, proximity to a financial centre* and *density of firms in energy* contribute the most to the high potential index while the indices of transport of freight, share of micro businesses and quality of university are slightly higher than the UK average (see Figure 28).

Figure 28 Energy potential in Edinburgh



Delfzijl en omgeving is one of the regions with the most potential in energy in the Netherlands. It has high indices in similar indicators to Edinburgh in the UK (see Figure 29) but the potential index is more driven by the high shares of employment than the density of firms.

Figure 29 Energy potential in Delfzijl en omgeving



5.1.8 Biotechnology

Biotechnology is a specialised sector with an especially larger range of indicators of both current status and future potential. Strength in biotechnology in a region is demonstrated by not only *shares of employment and firms* but also *R&D expenditure* and the *number of biotech patent applications*. The reason we included *R&D expenditure* as indicators of current status rather than future potential is because most of the activities taking place in this subsector are in research and development. Also, only regions which has a *number of major biotechnology companies or clusters* with high-quality research facilities is likely to spend more on R&D and have more innovations to apply for intellectual property protection. The number of biotech patent applications is expressed by *number of applications per 1000 employees.*

Indicators of future potential in the sector include the *population with upper secondary or tertiary education* and *quality of university in biological sciences* and *distance to a large financial centre* (London or Edinburgh) which all reflect the quality of the workforce, university facilities and access to high levels of funding considered as essential for biotechnology research. Once again, because almost all activities in this subsector are in R&D, the inclusion of R&D employment further demonstrates the scale of the sector relative to the region's economy.

It is not surprising that strengths in biotechnology are evident in **Cambridgeshire** and the regions of Greater London, especially **Inner London – West**. Both regions have prominent universities and research institutions carrying out high quality biomedical and biotechnology research, easy access to funding and a high share of R&D employment. The *SME birth rate* in London is also much higher than the UK as a whole. However, the current sector has some different features in the two regions. Cambridgeshire scores highly in all current status indicators, reflecting the *large number of clusters* and relocation of headquarters of major firms such as Astra Zeneca in Cambridge (see Figures 30 and 31). In contrast, in Inner London – West the only particularly high index is in biotechnology patents (see Figure 31). One reason may be the dominance of banking and financial industries in London, which reduces the scale of biotechnology relative to the whole economy.

Figure 30 Current status of Biotechnology in Cambridgeshire

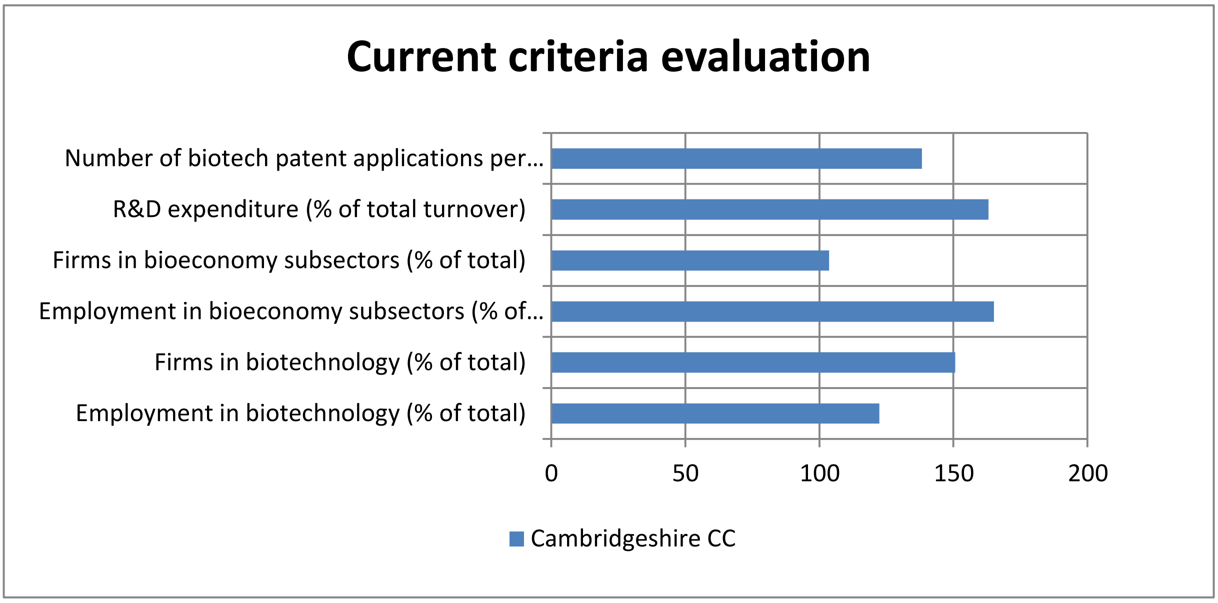
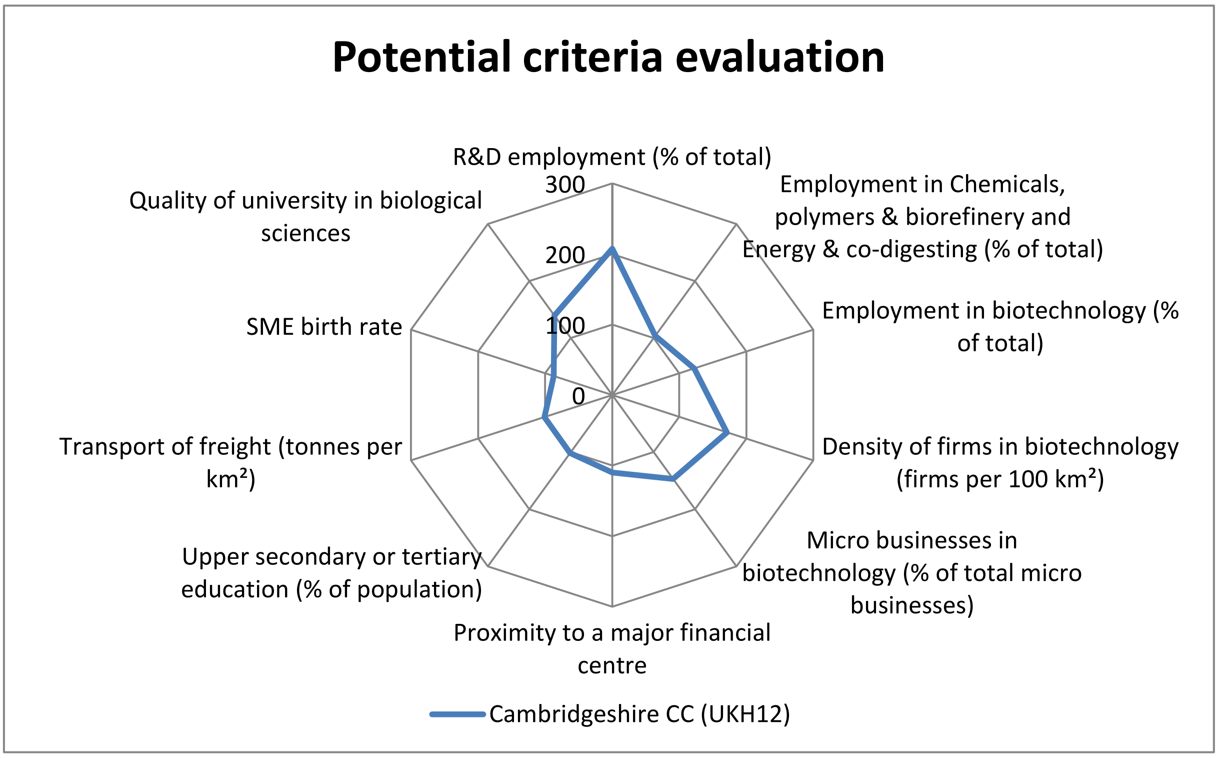


Figure 31 Biotechnology potential in Cambridgeshire



In the Netherlands, **Groot-Amsterdam** (Greater Amsterdam) and **Utrecht** are the only regions with biotechnology potential. Both regions have a relatively high SME birth rate and a high density of biotechnology firms. Greater Amsterdam benefits from the locally available funding and financial expertise (see Figure 33), while Utrecht performs slightly better in tertiary education and quality of university in biological sciences. However, the indices of potential in both regions are nowhere as evidently large as those in the UK. Like London, Greater Amsterdam is generally focused on finance and tourism, making R&D employment a smaller proportion of total employment compared to Groningen which shares with Cambridge in the UK some characteristics that make them both attractive to researchers.

Figure 32 Biotechnology potential in Inner London - West

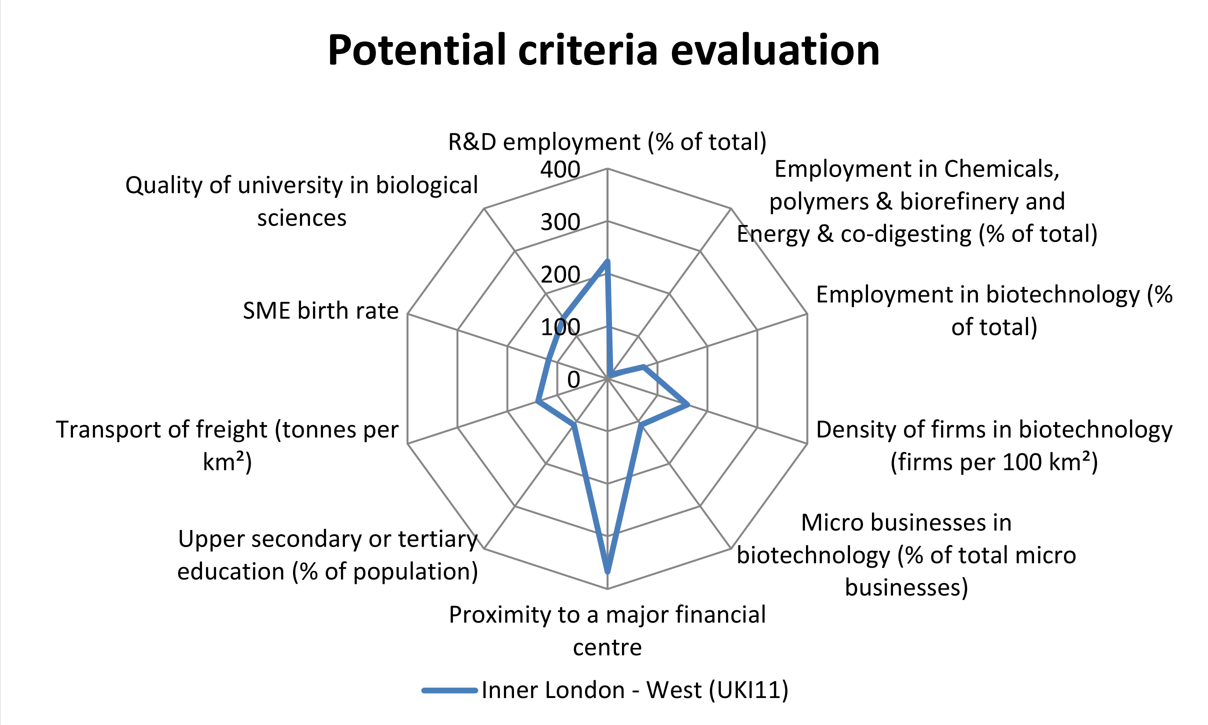
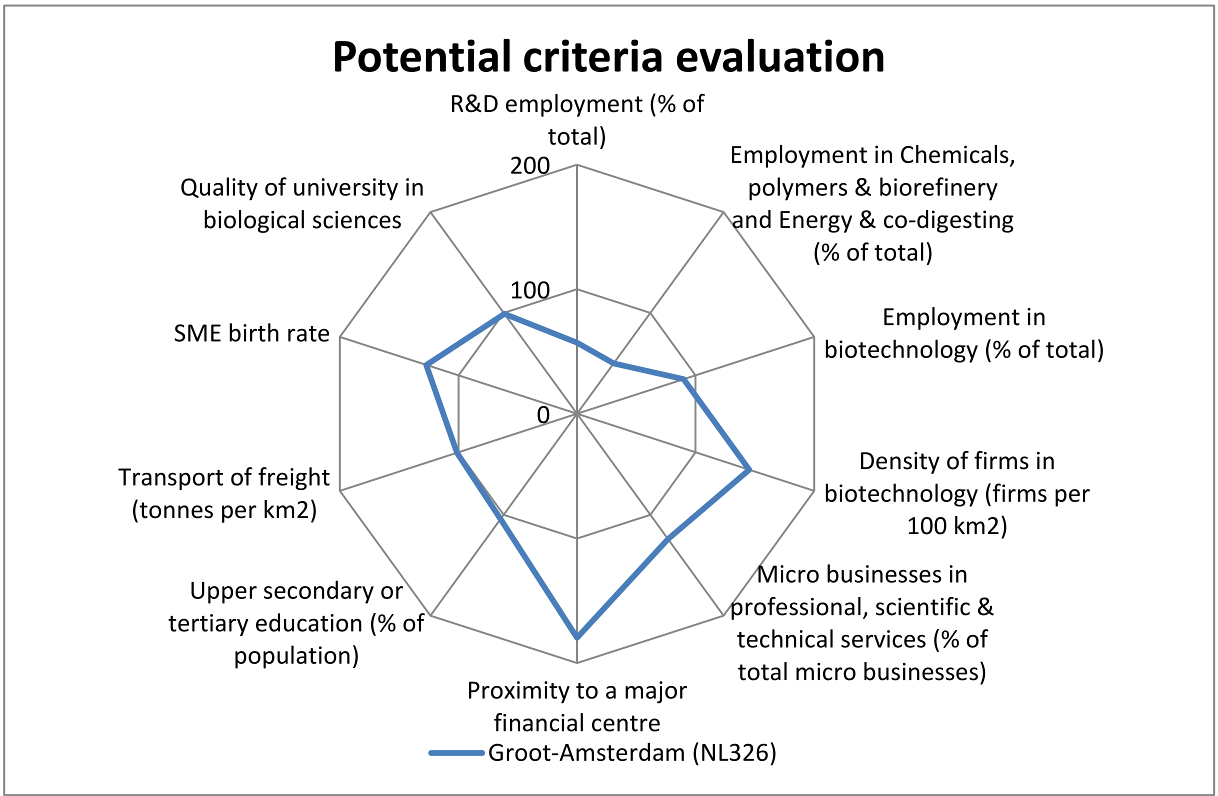


Figure 33 Biotechnology potential in Greater Amsterdam



5.2 Summary

Table 5 gives a summary of the group of potential bioeconomy sectors and their important criteria and indicators that can describe the development of these bioeconomy sectors. The indicators are grouped under economic, environmental or social criteria as defined in Table 1 (Section 4.4).

Table 5 Bioeconomy sectors and their important criteria and indicators

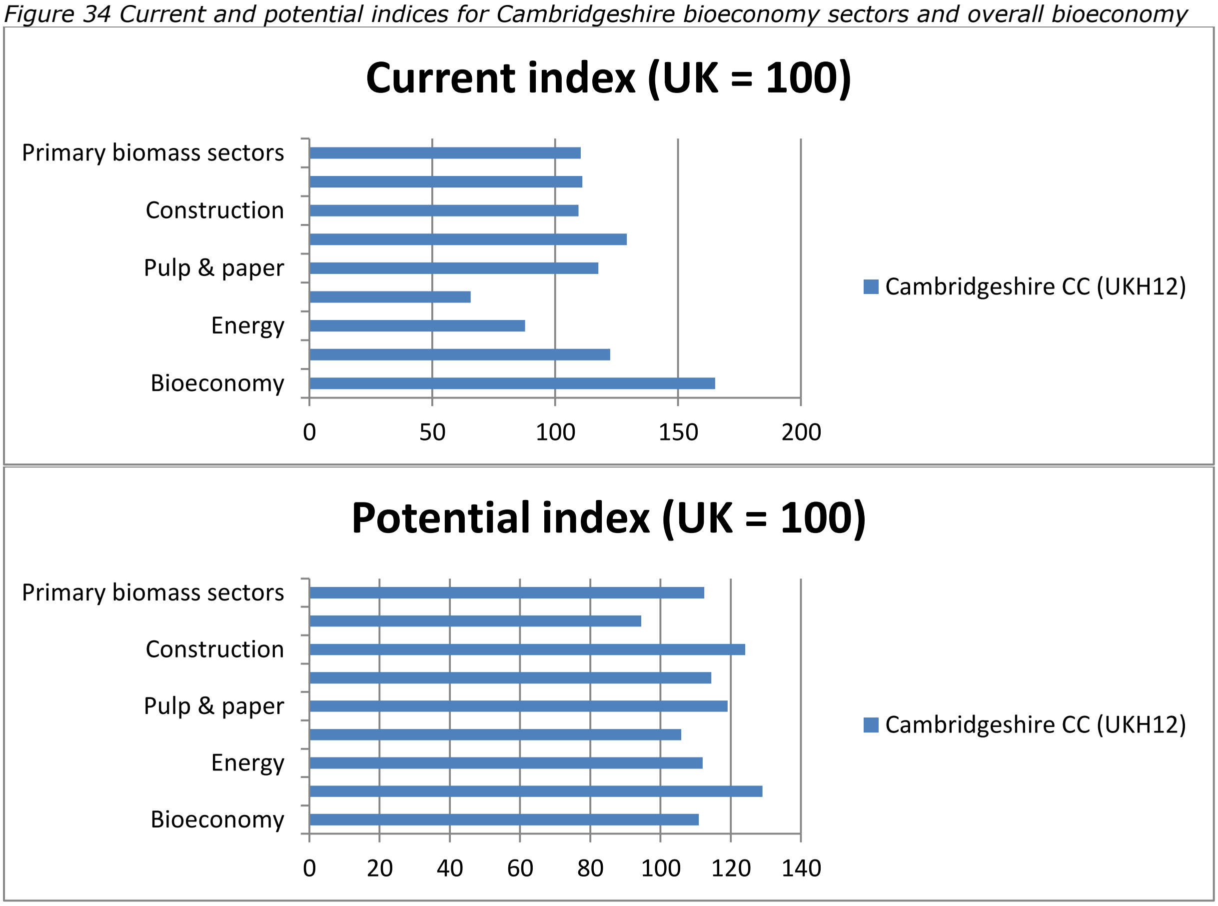
Bioeconomy Sector	Economic criteria	Environmental criteria	Social criteria
All	.R&D employment .Employment in Chemicals, polymers, biorefinery and Energy .Employment in bioeconomy .Firms in bioeconomy	.Transport of freight	.SME birth rate .Quality of university
Primary biomass sectors	.Employment in primary biomass sectors .Firms in primary biomass sectors .Density of firms in primary biomass sectors .Micro businesses in primary biomass sectors	.Agricultural biomass production .Marine biomass production .Forestry biomass production .Waste biomass production	
Food and feed processing	.Employment in food & feed processing .Firms in food & feed processing .Density of firms in food & feed processing .Micro businesses in food & feed processing .Proximity to a major financial centre .Upper secondary or tertiary education	.Agricultural biomass production .Marine biomass production	
Construction	.Employment in construction .Firms in construction .Density of firms in construction .Micro businesses in construction .Proximity to a major financial centre .Upper secondary or tertiary education	.Agricultural biomass production .Forestry biomass production	
Chemicals, polymers and biorefinery	.Employment in chemicals, polymers & biorefinery .Firms in chemicals, polymers & biorefinery .Density of firms in chemicals, polymers & biorefinery .Micro businesses in chemicals, polymers & biorefinery .Proximity to a major financial centre .Upper secondary or tertiary education .Extra-EU exports of chemicals & related products .R&D expenditure	.Agricultural biomass production .Forestry biomass production .Marine biomass production	
Pulp & paper	.Employment in pulp & paper .Firms in pulp & paper .Density of firms in pulp & paper .Micro businesses in pulp & paper .Proximity to a major financial centre .Upper secondary or tertiary education	.Agricultural biomass production .Forestry biomass production	
Textiles & clothing	.Employment in textiles & clothing .Firms in textiles & clothing .Density of firms in textiles & clothing .Micro businesses in textiles & clothing .Proximity to a major financial centre .Upper secondary or tertiary education	.Agricultural biomass production	

Bioeconomy Sector	Economic criteria	Environmental criteria	Social criteria
Energy	.Employment in energy .Firms in energy .Density of firms in energy .Micro businesses in energy .Proximity to a major financial centre .Upper secondary or tertiary education	.Agricultural biomass Production .Forestry biomass production ..Marine biomass production .Waste biomass production	
Biotechnology	.Employment in biotechnology .Firms in biotechnology .Density of firms in biotechnology .Micro businesses in biotechnology .Proximity to a major financial centre .Upper secondary or tertiary education .Biotechnology patent applications per 1000 employees .R&D expenditure		.Life expectancy at birth

** Due to the lack of data, exports of chemicals & related products is excluded for analysis of the Netherlands.*

The **potential index** for each group of bioeconomy sectors is calculated as the average of all indices of potential (as mentioned in the previous sections). The **current index** is represented by employment in that group as a percentage of total employment as for most groups the list of indicators describing the current status is dominated by employment and number of firms and employment is the more accurate measure of the scale of the subsectors. An index of more than 100 indicates the region has more potential for the development of bioeconomy in that group of bioeconomy sectors than the UK as a whole and whether there is great or little potential depends on its magnitude. Figure 34 gives an example of respectively the current and potential indices for the Cambridgeshire sector groups. However it should be noted that the current and potential indices are calculated using different methods, and should not be compared side-by-side.

Figure 34 Current and potential indices for Cambridgeshire bioeconomy sectors and overall bioeconomy



To emphasise the overall future potential aspect, an **overall potential index** for each NUTS3 region in UK and NL is also calculated for the bioeconomy as a weighted average of potential indices for all groups of subsectors. The weights are the employment share of each group of subsectors in total bioeconomy employment.

6. Findings and recommendations for next steps

This paper sets out a model for the operation of a regional bioeconomy, and identifies the characteristics of the development towards a potential successful bioeconomy, and the criteria and indicators that interact to form those characteristics.

Work Package 1 has brought together the partner's knowledge, the findings of the literature review and the experiences of regional partners, in determining the list of criteria and indicators suitable for describing the existence of the bioeconomy potential in a given region, within the theoretical structure developed in Chapter 3. The indicators have been quantitatively 'tested' to assess their validity, e.g. feedback on the analytical framework and the criteria identified was obtained from the regional stakeholder meetings. Moreover, the selecting of the set of indicators has gone along with the process of determining useful and smart indicators that are expecting (in this stage of the project) to support the conducting of case studies (Work Package 3) and the creating of regional profiles (Work Package 4).

Chapter 5, in addition to Annex A, sets out the quantitative assessment that has been tested and carried out for describing the current and potential bioeconomy in NUTS3 regions of the UK and the Netherlands. This can be used to confirm (or challenge) the results of the UK analysis, using detailed employment and company data that we have secured for the NUTS3 regions of the Netherlands[10]. However, the reliance on this detailed data limits how far this analysis can be taken further; without a central source of similarly detailed (4-digit NACE code) data for the other member states, it is impossible to carry out this exercise for more Member States. The piloting of two countries within Work Package 1 however is enough to demonstrate that the quantitative framework is robust, and can form the basis for the development of regional profiles in Work Package 4.

If the European Commission wish to take this analysis further (i.e. develop it for other Member States' NUTS3 regions), then it is recommended to work with the Bioeconomy Observatory project (coordinated by JRC-IPTS; project duration March 2013-Feb 2016), to collect the relevant indicators at a sufficiently detailed geographical and sectoral level.

The set of criteria and indicators that has been used in the quantitative assessment for describing the current and potential bioeconomy, is transferred into a Catalogue of Criteria and Indicators, which is one of the building blocks in the BERST toolkit to be developed in this project. This Catalogue is represented by an online BERST metabase module that is organising the data associated with each of the criteria (see, Deliverable 1.2). The metabase module will improve the BERST research process in terms of effectiveness, transparency and reproducibility, and it will ease the exchange of knowledge within the project teams and must improve the re-usability of data, classifications and procedures. In the course of the project, the approval of the selected indicators will be further tested in Work Packages 3 and 4, while the Catalogue of Criteria and Indicators (and the metabase) will be further populated with figures from case study regions and good practice regions.

The Catalogue of Criteria and Indicators (and the metabase) which sits alongside the analysis assessed in this report, includes the raw unadjusted figures for NUTS3 regions from e.g. Eurostat and extended with national UK and NL sources. In Work Package 4 this type of indicator data will be used to allow the benchmarking of both the current and potential performance of regions against those which are identified as 'Good Practice' in Work Package 3, in the same way that the analysis presented in this report measures them against the national average.

[10] BERST partner LEI bought data on employment and company numbers for bioeconomy sectors in all Dutch NUTS3 regions from LISA database. The sector specifications in this database correspond to the NACE - Statistical classification of economic activities (Eurostat).

Bibliography

Begg, I. (1999), 'Cities and Competitiveness', *Urban Studies*, 5-6: pp795-809.

Bio.be, (2013), 'Towards a Belgian and Regional Strategy for the Biobased Economy'.

Bioeconomy Council, (2012), 'Bioeconomy Innovation'.

Biomass Energy Europe, (2011), 'Final Report (BEE to European Commission)'.

Biomass Energy Europe, (2011), 'Executive Summary, Evaluation and Recommendations (BEE to European Commission)'.

Europe INNOVA, (2011), 'Sectoral Innovation Watch'.

European Commission, (2012), 'Innovating for Sustainable Growth: A Bioeconomy for Europe'.

European Commission, (2012), 'Innovating for Sustainable Growth: A Bioeconomy for Europe'.

European Commission DG JRC, (2013), 'Bioeconomy Information System and Observatory Project: Set up of the Bioeconomy Observatory'.

European Commission, (2013), 'Overview of the Systems Analysis Framework for the EU Bioeconomy'.

European Commission, (2011), 'The European Bioeconomy in 2030'.

European Commission, (2009), 'Preparing for our future: developing a common strategy for key enabling technologies in the EU'.

European Commision (DG Research), (2008), 'Regional Biotechnology: Establishing performance indicators for bioclusters and bioregions relevant to the KBBE area'.

Europe INNOVA, (2008), 'Do's and don'ts for biotech cluster development: the results of NetBioCluE'.

European Commission, (2007), 'Regional Research Intensive Clusters and Science Parks'.

European Commission, (2010), 'The Knowledge Based Bioeconomy in Europe'.

European Commission DG Regio (2013), 'The Guide to Multi-Benefit Cohesion Policy Investments in Nature and Green Infrastructure'.

Eduardo, Trigo and Guy, Henry, (2012), 'Scenarios for bioeconomy development in LAC'.

Formas, (2012), 'Swedish Research and Innovation Strategy for a Bio-based Economy'.

Kaplinsky, R., (2000), 'Globalisation and unequalisation: What can be learned from Value Chain Analysis'.

OECD, (2007), 'Reviews of Regional Innovation: Competitive Regional Clusters, National Policy Approaches'.

OECD, (2009), 'The Bioeconomy to 2030'.

OECD, (2005), 'A framework for biotechnology statistics'.

Panoutsou, C., Castillo, A. and Bauen, A., (2011), 'D2.2 Report on the main factor influencing biomass demand'.

PwC, (2011), 'Regional Biotechnology: Establishing a methodology and performance indicators for the assessing bioclusters and bioregions relevant to the KBBE area'.

Solvell, Lindqvist and Ketels, (2003), The Cluster initative Greenbook.

SAT-BBE, (2013), 'Data requirements for evaluating and monitoring the evolution of the bioeconomy'.

SAT-BEE, (2013), ' Tools for evaluating and monitoring the EU bioeconomy: Indicators'.

Teagasc, (2008) 'Towards 2030 - Teagasc's Role in Transforming Ireland's Agri-Food Sector and the Wider Bioeconomy'.

The Research Council of Norway, (2012), 'Research Programme on Sustainable Innovation in Food and Bio-based Industries'.

United Nations, (2004), 'The Biotechnology Promise - Capacity-building for Participation of Developing Countries in the Bioeconomy'.

UNIDO, (2001), 'Environmental and Industrial Biotechnology in Developing Countries'.

UNIDO, (2007), 'Industrial Biotechnology and Biomass Utilisation'.

Annex A: Data sources for indicator analyses

Tables A1 and A2 give the overview of the data sources for the indicators applied in chapter 5 to describe the current status and future potential of the regional bioeconomy sectors. The most currently available data at the time of collection were used for the analyses, the timing ranging from 2008 to 2013 for the UK and from 2010 to 2014 for the Netherlands (with the exception of agricultural and forestry biomass production). This table also includes sources of data which are then used to calculate or transformed into data for indices at the NUTS3 level. Such calculations are set out in details in Annex B.

Table A1 Data sources for UK analysis

Type of indicators	Level of data	Year of data	Type of source	Source
Employment	NUTS3	2012	National	Business Register and Employment Survey
Number of firms	NUTS3	2012	National	UK Business Counts
SME birth rates	NUTS3	2012	National	ONS Business Demography
Quality of university	NUTS3	2008	National	Research Assessment Exercise
Exports of chemicals & related products	NUTS1	2012	National	HMRC Regional Trade Statistics
R&D expenditure	NUTS1	2010	European	Regional Innovation Scoreboard
Agricultural biomass production	National	2005	European	Eurostat
Marine biomass production	National	2012		
Forestry biomass production	National	2007		
Waste biomass production	National	2012		
Transport of freight	NUTS3	2011		
R&D employment	NUTS2	2011		
Biotechnology patent applications	NUTS3	2010		
Upper secondary or tertiary education	NUTS2	2013		
Proximity to a major financial centre	NUTS1	2013		Cambridge Econometrics calculations

Table A2 Data sources for NL analysis

Type of indicators	Level of data	Year of data	Type of source	Source
Employment	NUTS3	2013	National	LISA
Number of firms	NUTS3	2013	National	LISA
Quality of university	NUTS3	2014	International	QS World University Ranking
R&D expenditure	NUTS1	2010	European	Regional Innovation Scoreboard
Agricultural biomass production	National	2005	European	Eurostat
Marine biomass production	National	2012		
Forestry biomass production	National	2007		
Waste biomass production	National	2012		
Transport of freight	NUTS3	2011		
SME birth rates	NUTS3	2012		
R&D employment	NUTS2	2011		
Biotechnology patent applications	NUTS3	2010		
Upper secondary or tertiary education	NUTS2	2013		
Proximity to a major financial centre	NUTS1	2013		Cambridge Econometrics calculations

** Due to the lack of data, exports of chemicals & related products are excluded from NL analysis.*

Annex B: Quantitative assessment of the UK and NL regional bioeconomy

See attached spreadsheets and see on-line Catalogue of Criteria and indicators. This Catalogue is one of the building blocks of the BERST toolkit to be developed in the project.

In this Annex B, we explain the methods developed to calculate:

1) indicators describing the current status and future potential of bioeconomy sectors;
2) indices for all indicators and bioeconomy sectors;
3) the *Potential Index* and *Current Index* for all groups of bioeconomy subsectors and the *Overall Potential Index* for bioeconomy.

B.1 Calculations of data for indexing

B.1.1 Proxies

For a number of desired indicators, data were not available; instead another indicator measuring a similar effect is used. These indicators used in the UK and NL analysis are listed in Tables B1 and B2 below.

Table B1 Proxies for selected indicators (UK analysis)

Group of bioeconomy subsectors	Desired indicator	Proxy
Used for multiple subsectors	SME birth rate	Business birth rate
	Biomass availability (including domestic production and imports of biomass)	Domestic production of biomass (in four separate categories: agricultural biomass, marine biomass, forestry biomass & waste biomass)
	Availability of funding	Distance to the closest major financial centre (London or Edinburgh)
	Cluster size (Number of clusters, number of firms and employees in each cluster)	Employment and number of firms in the group of bioeconomy subsectors, as a percentage of the region's total
		Density of firms in the group of bioeconomy subsectors (number of firms per 100 km²)
Chemicals, polymers & biorefinery	Sales of innovation products	Exports of chemicals & related products

Table B2 Proxies for selected indicators (NL analysis)

Group of bioeconomy subsectors	Desired indicator	Proxy
Used for multiple subsectors	SME birth rate	Business birth rate
	Biomass availability (including domestic production and imports of biomass)	Domestic production of biomass (in four separate categories: agricultural biomass, marine biomass, forestry biomass & waste biomass)
	Availability of funding	Distance to the closest major financial centre (Amsterdam, Luxembourg or Brussels)
	Cluster size (Number of clusters, number of firms and employees in each cluster)	Employment and number of firms in the group of bioeconomy subsectors, as a percentage of the region's total
		Density of firms in the group of bioeconomy subsectors (number of firms per 100 km²)

Primary biomass sectors	Small & micro businesses in primary biomass sectors	Small & micro businesses in agriculture, forestry & fishing
Food & feed processing	Small & micro businesses in food & feed processing	Small & micro businesses in manufacturing
Construction	Small & micro businesses in construction	Small & micro businesses in construction broad sector
Chemicals, polymers & biorefinery	Small & micro businesses in chemicals, polymers & biorefinery	Small & micro businesses in manufacturing
	Sales of innovation products	Exports of chemicals & related products
Pulp & paper	Small & micro businesses in pulp & paper	Small & micro businesses in manufacturing
Textiles & clothing	Small & micro businesses in textiles & clothing	Small & micro businesses in manufacturing
Energy	Small & micro businesses in energy	Small & micro businesses in electricity, gas, steam & air conditioning supply
Biotechnology	Small & micro businesses in biotechnology	Small & micro businesses in professional, scientific & technical services

B.1.2 Unit conversion and regionalisation

The majority of indicators are expressed in nominal terms, and do not have significant explanatory powers in sectoral and regional comparisons (as different levels may reflect overall region size, rather than bioeconomy specialisation). Converting the data into percentage (as with employment and the SME birth rate) or density (for example, crop yield and transport of freight) allows easier comparison between regions and makes it more straightforward to identify strengths (specialisation) and weaknesses (no specialisation) in that region. As set out in Table A1, some indicators are only available for NUTS1 or NUTS2 regions. In these cases the data for NUTS3 regions was constructed either by averaging out data across the constituent NUTS3 regions (i.e. assuming all NUTS3 regions have an equal share) or applying data directly to all NUTS3 regions within each NUTS1 or NUTS2 region which we have data for (i.e. assuming that ratios are held constant across constituent NUTS3 regions). The indicators that follow these methods are given in Table B3.

Table B3 Common methods of unit conversion and regionalisation

Type of indicator	Unit conversion method	Regionalisation method
Employment in each group of bioeconomy subsectors	Percentage of total employment	None
Employment in all bioeconomy subsectors (including primary biomass sectors)	Percentage of total employment	None
R&D employment	Percentage of total employment	NUTS2 data copied to NUTS3 level after conversion
Firms in each group of bioeconomy subsectors	Percentage of total number of firms	None
Density of firms in each group of bioeconomy subsectors	Number of firms per 100 km²	None
Small & micro businesses in each group of bioeconomy subsectors	Percentage of total number of small & micro businesses	None
SME birth rate	Percentage of total number of active enterprises	None
Biotechnology patent applications	Number of applications per 1000 employees	None
Exports of chemicals & related products	Percentage of regional GVA	NUTS1 data copied to NUTS3 level after conversion
Proximity to a financial centre	None	NUTS1 data copied to NUTS3 level after conversion
Upper secondary or tertiary education	None	NUTS2 data copied to NUTS3 level after conversion

For indicators of biomass production, in the absence of a measured national average, a proxy is calculated as a weighted average of the NUTS3 regions. For example, in the case of agricultural biomass production, the average is the total level of production in all regions, each region weighted by its share of the national agricultural land area. Similarly, weights are shares of the national woodland area for forestry biomass, shares of the national water area for marine biomass and shares of agricultural employment for waste biomass.

In the Regional Innovation Scoreboard (RIS), R&D expenditure as a percentage of total turnover is expressed as an index to the EU average with a value of one indicating the same share of total turnover as in the EU as a whole. Where this data is used in the indices, for each of the NUTS1 regions where data are provided, the RIS data are assumed to be the same for al constituent NUTS3 regions within a given NUTS1 region, and the national average is the average of all NUTS1 regions.

The indicator of university quality required substantial processing to take account of the size of universities and map them to the relevant regions. In the UK, the Research Assessment Exercise (renamed the Research Excellence Framework and due to take place again later in 2014) provides data for the number of full-time research staff and the percentage of research activities carried out at different levels of quality, by university and subject. The percentages of activities at the high quality levels, 3* and 4*, are multiplied by the number of staff and summed to obtain an indicator measuring the total number of staff doing high quality research at each university. The NUTS3 level data is the total of all universities within each NUTS3 region; where a university has campuses in more than one regions, it is counted in all of them.

This process is completed for all groups of subsectors which have quality of university as an indicator within their indices. The difference between the data in each subsector is the subject(s) related to each group (Table B4).

Table B4 Subjects related to group of bioeconomy subsectors

Group of subsectors	Subjects for UK analysis	Subjects for NL analysis
Primary biomass sectors	Agriculture, veterinary & food science	Agriculture & forestry
Food & feed processing	Agriculture, veterinary & food science	Agriculture & forestry
Construction	Metallurgy & materials; Civil engineering	Materials sciences; Civil & structural engineering
Chemicals, polymers & biorefinery	Chemistry; Chemical engineering; Pharmacy	Chemistry; Chemical engineering; Pharmacy & pharmacology
Pulp & paper	Metallurgy & materials	Materials sciences
Textiles & clothing	Matallurgy & materials	Materials sciences
Energy	Chemistry; Chemical engineering; General and Mineral & mining engineering	Chemistry; Chemical engineering
Biotechnology	Biological sciences	Biological sciences

A different source of data were used for the Netherlands; the QS World University Ranking. This lists all universities under a set of criteria one of which is the number of citations per paper. Each university is given a score on a scale of 100 that is directly related to the number of citations per paper in a specific subject. The same method of regionalisation is used as applied to the UK data, assigning each university to a NUTS3 region and averaging the scores of all universities to get the national average. The subjects related to each group of subsectors are similar to the UK analysis. This source offers global coverage which is useful when expanding the analysis to other EU Member States. However the dataset is less complete (containing fewer universities per country) and the raw data is already in some form of an index; both could alter the results to a great extent.

To distinguish types of biomass and include the most relevant for each group of bioeconomy subsectors, production of biomass is made up of four categories. Crops are classified under agricultural biomass, wood under forestry biomass, fishery (caught and aquaculture) under marine biomass and waste biomass is represented by industrial waste generated from the agriculture, forestry & fishing sector. Data for each category are obtained at the national level and regionalised to the NUTS3 level using appropriate weights. The areas of agricultural land and woodland in the NUTS3 region as a percentage of the national total are suitable weights for agricultural and forestry biomass respectively while the water area is applied for marine biomass. For waste biomass, employment in agriculture, forestry & fishing in the NUTS3 region relative to the nation indicates the level of activity in the sector which implies the level of waste generation. A region accounting for a larger proportion of agricultural employment in the country is likely to produce more agricultural waste.

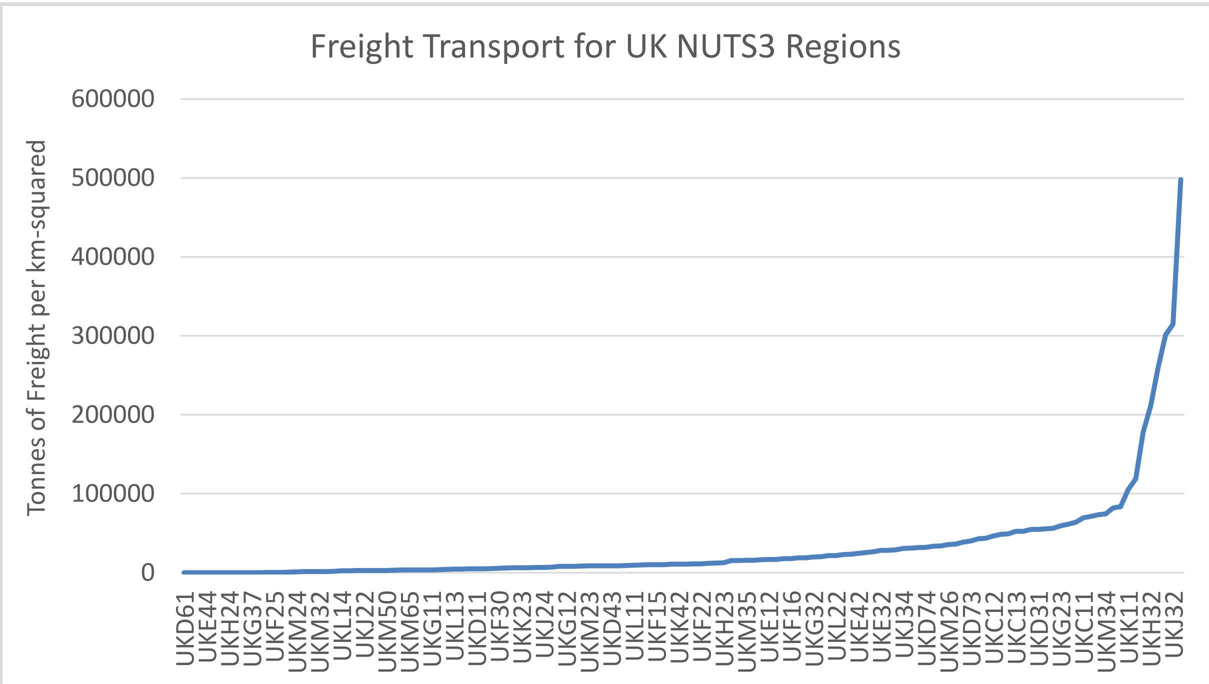
B.1.3 Composite indicators and additional transformation

Where indicators were found to be correlated, they were either combined into one metric or one of the variables was removed.

R&D expenditure is a composite indicator of R&D expenditure in the public sector and R&D expenditure in the business sector. After the necessary regionalisation, the average of both sets of data is used as inputs for the index.

Similarly, to measure strengths in infrastructure, a composite indicator was created using data for all modes of transport to avoid double counting. The tonnage of freight is available at the NUTS3 level from the original data for road transport and carried down from the corresponding NUTS2 level for air and marine transport. Data for all modes are then combined to obtain the total tonnage of freight transported and divided by the land area to make transport of freight density which is more comparable. In ascending numerical order, the plot of the original values reveals a clear exponential trend which can potentially distort the final indices (see Figure B1) with very high values for some regions (particularly those with a transport hub, e.g. a port, located within them. We considered the most suitable way to eliminate this exponential trend was to take the natural log of the data before indexing.

Figure B1 Exponential trend in infrastructure indicator



example). The most suitable way to eliminate an exponential trend is to take the natural log of the data before indexing. Tables B5 and B6 list all indicators for which a log transformation is required in the UK and Netherlands analyses.

Table B5 Indicators with log transformation in UK analysis

Group of bioeconomy subsector(s)	Indicator(s) with log transformation
Used in multiple subsectors	Transport of freight Proximity to a major financial centre Firms in bioeconomy Agricultural biomass production Marine biomass production Forestry biomass production Waste biomass production Quality of university in agriculture, veterinary & food science Quality of university in metallurgy & materials
Primary biomass sectors	Employment in primary biomass sectors Firms in primary biomass sectors Employment in agriculture Small & micro businesses in primary biomass sectors
Food & feed processing	Employment in food & feed processing Firms in food & feed processing Density of firms in food & feed processing Small & micro businesses in food & feed processing
Construction	Employment in construction Density of firms in construction Quality of university in metallurgy & materials and civil engineering
Chemicals, polymers & biorefinery	Density of firms in chemicals, polymers & biorefinery Quality of university in chemistry/chemical engineering/pharmacy
Textiles & clothing	Employment in textiles & clothing Firms in textiles & clothing Employment in textiles & clothing Density of firms in textiles & clothing Small & micro businesses in textiles & clothing
Pulp & paper	Employment in pulp & paper Firms in pulp & paper Employment in forestry/wood Density of firms in pulp & paper Small & micro businesses in pulp & paper
Energy	Employment in energy Firms in energy Quality of university in energy-related subjects Density of firms in energy Small & micro businesses in energy
Biotechnology	Employment in biotechnology Firms in biotechnology Biotech patent applications per 1000 employees Quality of university in biological sciences Density of firms in biotechnology Small & micro businesses in biotechnology

Table B6 Indicators with log transformation in Netherlands analysis

Group of bioeconomy subsector(s)	Indicator(s) with log transformation
Used in multiple subsectors	Transport of freight Proximity to a major financial centre Marine biomass production Forestry biomass production
Primary biomass sectors	Density of firms in primary biomass sectors
Construction	Density of firms in construction
Chemicals, polymers & biorefinery	Employment in chemicals, polymers & biorefinery Density of firms in chemicals, polymers & biorefinery
Textiles & clothing	Employment in textiles & clothing Density of firms in textiles & clothing
Pulp & paper	Density of firms in pulp & paper
Energy	Density of firms in energy
Biotechnology	Employment in biotechnology Firms in biotechnology

B.2 Index

B.2.1 Index for all indicators

After the required conversions, all data are indexed by dividing by the national average and then multiplying by 100. An index of greater than 100 indicates that the region performs better than the national average in the selected indicator. In contrast, an index value below 100 implies underperformance compared to the country as a whole.

The only exception where this indexing method was not strictly followed was proximity to a major financial centre. The index for this indicator is the reciprocal of the index that would otherwise be produced using the conventional method outlined above. If the original data were used to compute the index, a region situated closely to London or Edinburgh (in the UK) and Amsterdam, Luxembourg or Brussels (in the case of the Netherlands) would have a lower index suggesting an underperformance. The reciprocal keeps the relative scale constant for all regions while truly implying what the index is intended to (that a value above 100 represents a relative strength).

The accompanying excel spreadsheet "UK NUTS3 Bioeconomy Potential and Current Performance" and "NL NUTS3 Bioeconomy Potential and Current Performance" contain the converted data and indices for all indicators. The indices are put into charts to summarise the indicators describing the current status and those describing future potential of a group of subsectors in a NUTS3 region. The charts show not only how specialised a region is in a group of subsectors but also the indicators that are driving that specialisation.

B.2.2 Current and Potential Indices

For each group of subsectors, the ***Current Index*** is represented by employment in the group of subsectors as a percentage of total employment. The ***Potential Index*** is calculated as an average of all indicators of future potential. The same concept applies to the calculation of both overall indices but for most groups of subsectors, it is difficult to demonstrate the actual current status without detailed qualitative analysis, as a large proportion of the activity carried out even in a 4-digit NACE code relevant to bioeconomy may not be bioeconomy-focussed. Between the employment and number of firms' indicators, employment appears to have more complete data across sectors and regions and so makes a more suitable Current Index. It also accounts for the case where a factory or branch of a chain is located in a region, therefore contributing to employment but not being counted towards the number of firms.

We also produced an regional **Overall Potential Index** as an indicator of future bioeconomy potential. The index is a weighted average of potential indices of all groups of bioeconomy subsectors in a specific region. Employment in a group of subsectors relative to total bioeconomy employment is used as weights, to ensure that the final index reflects at least partially the current employment mix.

In the spreadsheets "UK NUTS3 Bioeconomy Overview" and "NL NUTS3 Bioeconomy Overview", both the Current Indices and the Potential Indices for all groups of subsectors and the Overall Potential Index for the bioeconomy are displayed for each region. The bar charts provide a brief overview of the regional bioeconomy in addition to the detailed analysis as described in section B.2.1.