

Scoping and sizing the Scottish Adaptation & Resilience (Climate Change) (A&RCC) Economy: An overview of methods

Mike Bonaventura
April 2018

Executive summary

Aims and findings

The Committee on Climate Change has highlighted the need for evidence to support analysis of the business opportunities from a changing climate. This paper makes recommendations on how to progress the scoping and sizing of the Adaptation & Resilience (Climate Change) (A&RCC) Economy based on:

- characteristics of previous assessments of the 'green economy';
- potential definitions of the sector based on these analyses;
- potential data sources; and
- options for a baseline study for Scotland.

National statistics agencies do not currently collect data on adaptation and resilience goods and services. However, the methods that were developed to collect data for two other segments of the 'green economy' - Environmental Goods and Services Sector (EGSS) and the Low Carbon & Renewable Energy (LCRE) Economy – have been used by the UK and several 'City Region' Governments to inform methods for scoping and sizing the market for A&RCC goods and services.

The A&RCC Economy involves companies operating across multiple, vertical industry Sections, Divisions and Groups (ONS, 2007). Therefore, to assess the potential value of products used to adapt or become resilient to a changing climate, the economy first has to be (horizontally) scoped. A bottom-up approach can be used, disaggregating product descriptions to a level that is sufficiently detailed that the actual intent, use or purpose of a product can be understood; something which is not always possible using just a description of what a product is. Data on the companies providing those products can then be mapped accurately from appropriate sources to the resulting 'product lines' before aggregating back up to a level appropriate to the analysis that is required.

A baseline for goods and services contributing to economic activity associated specifically with adaptation and resilience to climate change (A&RCC) was established in 2012 (BIS, 2013b). The method was updated for the reporting year 2012/13 to include activities identified in the fifth IPCC Assessment Report (AR5): *Impacts, Adaptation and Vulnerability* (IPCC, 2014; kMatrix, 2014a).

Based on that data, the A&RCC economy in the UK was valued at £6.3Bn by turnover, generated by

ClimateXChange is Scotland's Centre of Expertise on Climate Change, providing independent advice, research and analysis to support the Scottish Government as it develops and implements policies on adapting to the changing climate and the transition to a low carbon society.

4,080 companies employing 76,000 people. In Scotland, the economy was valued at £563m, with 344 companies employing 6,472 people.

To capture changes to the baseline, DEFRA commissioned the Office of National Statistics (ONS) to look at the feasibility of implementing an annual data collection survey for the A&RCC economy (ONS, 2015, 2016). Unfortunately, the lack of a clear and agreed definition of what adaptation goods and services actually were stalled that initiative. No economy-wide update to the A&RCC Economy baseline has been made since 2012/13. Given year-on-year growth of around 3% between 2008 and 2013, this baseline is no longer useful.

Recommendations

1. To tender a baseline assessment of the Scottish A&RCC Economy. In order for the assessment to incorporate the learning from the earlier A&RCC work and similar analyses, we recommend that the baseline is created with the following characteristics:

- a. **Variables:** key measures
 - ONS and Scottish Business Statistics use turnover, employment and the number of companies (ONS, 2017c; Scottish Government 2017)
- b. **Activities:** to be included in the study
 - IPCC WGII AR5 activities are a superset of the 'revised DEFRA' activities used in the early A&RCC studies and are preferred in scoping the A&RCC economy.
- c. **Scope:** inclusion criteria for the supply chain
 - Indirect (supply chain) producers contribute to the A&RCC economy and are generally included in economic impact assessments where their contribution to a sector is significant (>20%)
- d. **Product inclusion criteria:** the intent, use or purpose of adaptation goods and services and the (climate-related) hazards they address
 - The classification scheme needs to be (able to be) disaggregated to a level where the intent, use or purpose of a product can be determined. This may be lower than the level at which analysis usually takes place.
- e. **Apportionment:** for companies only partially operating in the A&RCC economy
 - A minimum threshold (floor) that at least 20% of company turnover has to be derived from the A&RCC economy for the company to be included in the economy would be in line with the studies cited below.
Only the A&RCC specific turnover should be included in value estimates
- f. **Data:** availability, quality and maintenance
 - A fully referenced list of data sources used in developing the baseline should be available to enable transparency.
A regular schedule for updating the underlying datasets will be required. Different timetables need to be considered in line with SCCAP milestones: annual progress reports, biennial independent assessments, 5-yearly SCCAP publication cycle.
An open data interface would enable additional analyses to take place over and above that provided by the supplier.
- g. **Accuracy:** confidence factors
 - A minimum confidence factor for data should be established for each stage of dis/aggregation; 85% is standard in the studies cited below.

h. **Alignment:** of the method with ONS, UN SEEA accounting principles

- By including indirect producers in the economy as outlined at (c) above the baseline will not conform with the UNSEEA-CF (2012) standard or the generally agreed principles governing the UK Environmental Account maintained by ONS.

Options to provide separate estimates of the economy for direct and indirect producers should be explored.

i. **Analytical capability:** comparators; breadth of benchmarking; depth of analysis (including the separation of climate-related products from the broader Adaptation and Resilience (A&R) economy.

- This study has not considered the resource implications of different analytical capabilities. However, we suggest:

- a breakdown and comparison between the 32 Scottish Local Authorities would be useful
- comparisons with other UK, EU or global countries, regions or cities would also be useful, although this would need normalising to be very meaningful. Normalisation factors might include: GVA (per head), working population, company numbers by size and activity, etc.

2. To develop a method to support periodic updates to the baseline dataset to enable year-on-year comparisons and start to develop a time series for the A&RCC Economy.

The baseline dataset could be used to stratify a sampling frame, providing a statistically representative sample of economic producers operating in the A&RCC Economy who could then be regularly surveyed.

A survey has the potential to provide much richer insight into the details of the A&RCC Economy. It would though need to take account of the issues raised in the consultation following the ONS Feasibility Study for a Climate Change Survey (§2.2.1) (ONS, 2015, 2016).

Where a survey-based approach is judged to be infeasible for reasons of cost, burden or inherent limitations in the design, a regular update directly to the baseline dataset could be explored as outlined in point (f) above.

Finally, there are other projects taking place in Scotland that have similar objectives to the work described here, albeit at different scale. The regional assessment of the adaptation economy of the Glasgow City Region and Scottish Enterprise's assessment of the risks and opportunities for the six key growth sectors are two; there may be others. Any future research should consider potential synergies with these projects.

Content

Executive summary.....	1
1 Defining and measuring the ‘green’ economy’.....	5
1.1 The Environmental Goods and Services Sector (EGSS)	5
1.2 Low Carbon and Renewable Energy (LCRE) Economy	7
2 Studies of the Adaptation & Resilience (Climate Change) (A&RCC) Economy	9
2.1 Economy-wide studies	9
2.2 Sampling studies	12
2.2.1 Open sampling frame	12
2.2.2 Proprietary sampling frame	13
2.2.3 Selective sampling frame	15
3 Lessons learned	16
4 Data sources.....	17
4.1 Primary research	17
4.2 Secondary research	17
5 Conclusions & recommendations.....	18
6 References	18
7 Bibliography	23
8 Contacts	24
9 Company contacts	25

1 Defining and measuring the 'green' economy'

The Committee on Climate Change has highlighted the need for evidence to support analysis of the business opportunities from a changing climate. This paper makes recommendations on how to progress the scoping and sizing of the Adaptation & Resilience (Climate Change) (A&RCC) Economy based on:

- characteristics of previous assessments of the 'green economy';
- potential definitions of the sector based on these analyses;
- potential data sources; and
- options for a baseline study for Scotland.

National statistics agencies do not currently collect data on adaptation and resilience goods and services. However, the methods that were developed to collect data for two other segments of the 'green economy' - Environmental Goods and Services Sector (EGSS) and the Low Carbon & Renewable Energy (LCRE) Economy – have been used by the UK and several 'City Region' Governments to inform methods for scoping and sizing the market for A&RCC goods and services.

Donna Livesey's 2010 paper summarises the challenges in measuring the environmental goods and services sector (Livesey, 2010):

- **Measurement:** the limitations of (vertical) sector classification systems (SIC2007, NACE Rev.2, PRODCOM, etc.) means that supplementary research will be required to identify the producers contributing to the economy.
- **Supply chain (extent):** to what extent, if at all, do supply chain (indirect) producers contribute.
- **Completeness of coverage (scope):** as the economy is emergent, no database of goods and services can be considered exhaustive. The on-going innovation and continuous evolution of the industry makes the maintenance of databases an important consideration in developing time series for year-on-year comparison as new activities are identified for inclusion.
- **Requirements:** the number of producers operating in the sector, the number of people they employ and their contribution to the economy are the minimum required to understand the value of the economy. However, requirements may also include a capability to compare the relative profitability and productivity of the environmental and non-environmental sectors; the capability to understand regional, national and international variations and competitiveness; and the potential for growth, particularly in relation to jobs.

The same challenges exist in scoping and sizing the A&RCC Economy. Lessons learned in developing the methods currently used to assess the Environmental Goods and Services Sector (EGSS) and the Low Carbon & Renewable Energy (LCRE) Economy can be used to inform the present work.

1.1 The Environmental Goods and Services Sector (EGSS)

For most of the 19th and 20th Centuries, the market for traditional environmental goods and services was driven primarily by legislation. Whether at the international level (e.g. Montreal Protocol, EU Directives), the national level (e.g. Clean Air Act, Landfill Tax regime) or locally (e.g. Town and Country Planning Act), legislation has created, strengthened and largely shaped the 'environmental' sector.

Work by the OECD and European Commission to develop the framework to collect statistics on this sector began in the early 1990s when a series of reports and country studies were published. In 2009, Eurostat (the Statistical Agency of the European Commission) published a data collection handbook (European Commission, 2009a) to support National Statistics Institutes (NSIs) in the collection of

official statistics, and standard tables were established for an EU data collection pilot (European Commission, 2009b).

The Handbook defined the Environmental Goods and Services Sector (EGSS) with respect to “*technologies and products (goods and services) [that] satisfy the end purpose criterion, meaning they must have an environmental protection or resource management purpose as their prime objective*”. (Eurostat Data Collection Handbook: Box 1, p.48).

At about the same time (2010) the United Nations Statistics Division was consulting globally on the UN System of Environmental Economic Accounting (UNSEEA)¹. It proposed that the measurement of the environmental goods and services sector would be based on the methodology outlined in the Eurostat Handbook and would form part of the core international standard on environmental economic accounting.

The resulting Central Framework (SEEA-CF, 2012) remains the internationally agreed standard for concepts, definitions, classifications, accounting rules and tables for producing accounts on the environment and its relationship with the economy (UN, 2014). The SEEA-CF uses concepts, definitions and classifications consistent with national accounts, enabling comparisons of the results of the environmental-economic accounts with aggregates of the national accounts, such as GDP.

In the UK, submission of the EGSS accounts became mandatory in 2017. They now form part of the UK Environmental Accounts² although the methods used to estimate them remain ‘experimental’.³ The sector includes the range of environmental goods and services, including environmental protection and resource management specific services, environmental sole-purpose products, and adapted goods. The accounts present the following characteristics of the sector: output, gross value added, employment and exports. The estimates are broken down by the 21 Standard Industrial Classification (SIC) sections (ONS, 2007) and by the Eurostat functional classifications of environmental protection and resource management (CEPA and CReMA).⁴

The January 2017 bulletin (ONS, 2017a) estimated that the environmental goods and services sector (EGSS) contributed:

- £29.0 billion to the UK economy in terms of value added in 2014 (1.6% of GDP);
- £61.1 billion on a production output basis in 2014, growing 18.7% between 2010 and 2014; and
- 373,500 full-time equivalent (FTE) jobs to total employment in 2014; an increase of 10.9% between 2010 and 2014.

Waste management activities accounted for the largest proportion of output at £12.7 billion (20.9%), gross value added at £5.2 billion (18.0%) and employment with 127,300 FTE jobs (34.1%) in 2014. They have done so every year between 2010 and 2014.

Between 2010 and 2014, the value added from production of renewable energy activities more than doubled from £2.2 billion to £4.5 billion.

Definitions of all nineteen (19) EGSS activities are included in the Methodology Annex (ONS, 2017b). Five (5) EGSS activities accounted for the majority of the output (71.8%), GVA (72.7%), and employment (56.9%) in 2014.⁵

¹ UN System of environmental economic accounting (SEEA): <https://unstats.un.org/unsd/envaccounting/seea.asp> & seea.un.org

² These are “satellite accounts” to the main UK National Accounts formally adopted into the HM Treasury Blue Book in 1999. Also included in the UK Environmental Account are the Environmental Protection Expenditure (EPE) accounts and Environmental Taxes accounts

³ Experimental statistics have not been presented to the UK Statistics Authority for assessment: www.ons.gov.uk/methodology/methodologytopicsandstatisticalconcepts/guidetoexperimentalstatistics

⁴ Eurostat CEPA (environmental protection) / CReMA (resource management) activities

⁵ Waste management, renewable energy production, recycling, wastewater, water quantity management.

1.2 Low Carbon and Renewable Energy (LCRE) Economy

Since the 1990s, climate change has become a key and growing influence on legislation. This has stimulated new and emerging business sectors focusing on lowering carbon emissions and a growing financial sector focused on investment in low carbon markets and trading new environmental commodities.

The *low carbon economy*, or more recently the *low carbon and renewable energy economy* is defined by ONS as “*economic activities that deliver goods and services that generate significantly lower emissions of greenhouse gases; predominantly carbon dioxide*”. Unlike the environmental goods and services sector, it is a concept developed specifically in response to UK government policy requirements and is unique to the UK. There is no internationally accepted definition or agreed way to measure a low carbon economy. The statistics gathered are not comparable with national accounts concepts although they are comparable with other business statistics such as those collected through the UK Annual Business Survey.

Like the environmental goods and services sector, early attempts to measure the market for low carbon and environmental goods and services (LCEGS) recognised significant limitations in using Standard Industry Classifications to identify the economic producers in the sector (Selwyn & Leverett, 2006). Other classification schemes were no more useful in gathering statistics across the economy.⁶ Producers existed across industry *Sections, Divisions* and *Groups*; the sector was ‘horizontal’ rather than ‘vertical’. These studies concluded that these classification systems would need to be supplemented by comprehensive research to help define the sector using additional data sources, including the ONS Inter-departmental Business Register (IDBR), surveys, trade associations and professional bodies, and intellectual property offices for registered patents.

The industry analysis commissioned in 2009 by the Department of Business, Enterprise and Regulatory Reform (BERR, the forerunner of BIS and BEIS) segmented the economy into three (3) primary areas of activity (Level 1) - *Environmental, Renewable Energy* and *Emerging Low Carbon* (Sharp, 2009). These three were subsequently disaggregated into twenty-three (23) sub-sectors (Level 2) and ninety-five (95) sub-sub-sectors (Level 3) to identify 2,490 discrete activities. Each level has its own ‘defined analytic benefits’.⁷

Producers across the supply chain were included where at least 20% of their sales was supplied into the LCEGS sector and only the sales activity relating to the sector was included in evaluating the economy. This is similar to how other sectors of the economy are measured and generally includes contributions from R&D, through manufacturing into distribution, retail, installation and maintenance services. However, it is different from Eurostat accounting practices which only include main producers; supply chain producers are only included if their product has no wider application.

This provided an initial estimate (2007/08 data) of a UK market value of around £106Bn - valuing it somewhere between healthcare and the construction sector:

- Nearly 80% of this value (£84.4Bn) was derived from the Renewable Energy (£31.1Bn) and Emerging Low Carbon (£53.3Bn) markets, categories not included in contemporary estimates of the Environmental Goods and Services Sector.
- Environmental goods and services themselves contributed £22.3Bn to the overall economy
- Almost half of these values were from the extended supply chain.

⁶ PRODCOM (Product of the European Community), for example, which combines NACE Rev2 & Classification of Product by Activity (CPA). The UK PRODCOM Survey is based on 4,000 products and covers 21,500 businesses: www.statistics.gov.uk/statbase/Product.asp?vlnk=15281. Equivalent issues exist in using the UK Standard Occupation Codes (SOC) in identifying green professions and skills.

⁷ Level 1 is used to select the top 52 global countries and for sub-national analysis; Level 2 is used for identifying market growth trends; and Level 3 for analysing regional low carbon sector performance in the UK.

- The sector contributed 881,000 full-time equivalent (FTE) jobs to total employment, almost half of which were in Emerging Low Carbon industries. Around half of these (445,000) were jobs with main producers, not the supply-chain
- Of the 54,835 producers contributing to the economy, 17,303 were in manufacturing and 91.5% were SMEs.

Scotland ranked 7th within the 12 UK regions identified, with a market value of £8.5Bn - Environmental, £2.1Bn, Renewable Energy, £2.6Bn and Emerging Low Carbon £3.8Bn; the accompanying analysis of sectoral strength is informative. There were 4,098 producers contributing to the economy, employing 73,000 people. Scottish output accounted for 8% (£849m) of UK exports from the sector.

Subsequent studies (kMatrix 2011, 2012; BIS 2013a) provided “an on-going analytical baseline” for the low carbon environmental goods and services economy: a sub-sector added in reporting year 2011/12, for example, introduced around 300 new activities.

The final report in July 2013 valued the UK economy at £128.1Bn (by sales) - just under 4% of global sales - derived from 51,292 producers (essentially static over the 3 previous years) employing 937,923 (also static). Scotland remained in 7th place of the 12 UK regions by value of sales (£10.1m), 7th by number of producers (4,192) and 5th by employment (77,702).

A number of regional assessments have also been produced for Manchester (kMatrix & Gyron 2013a), Cumbria (kMatrix & Gyron, 2013b), Liverpool City Region (kMatrix & Gyron, 2013c, 2014) and London (kMatrix, 2015).

Against the 2011/12 baseline, in 2014 the Department of Business, Innovation and Skills (BIS)⁸ commissioned Trends Business Research (TBR)⁹ to develop a more targeted method that would improve the accuracy of the estimates of the low carbon economy specifically (TBR, 2015). This in turn informed the design of the ONS Low Carbon and Renewable Energy (LCRE) Economy Survey which since 2015 has collected information on turnover, imports, exports, employment, and acquisitions and disposals of capital assets for 17 low carbon sectors organised into 6 thematic groups.¹⁰ Results are also presented by SIC code, allowing for some comparison with other measures (EGSS, for example).

The survey was distributed for the second time in 2016 for the reporting year 2015, to a sample of around 14,000 businesses. Importantly, unlike the baseline, the survey does not collect information on the supply chain involved in low carbon activities and only the portion of a business’s economic activity that directly relates to low carbon activities is included in the market valuation.

For 2016 (latest data), the LCRE Economy grew by 5% year-on-year to £42.6Bn by turnover with 84,500 producers (a decline of 20% on the previous year) employing 208,000 people (an increase of 3%). In Scotland, turnover was £5.8Bn (+8%), with 9,000 businesses (-50%) employing 24,000 people (+9%)

Together with the EGSS, the LCREE survey results are also now included in the annual UK Environmental Accounts (ONS, 2017a).

Unfortunately, excluded from the scope of both the EGSS and LCEGS statistics are goods and services produced for purposes that, “while beneficial to the environment, primarily satisfy technical, human and economic needs or that are requirements for health and safety. Goods and services

⁸ Now Business, Energy and Industrial Strategy (BEIS)

⁹ Now TBR/OrtusER

¹⁰. The 6 groups are: (a) low carbon electricity, (b) low carbon heat, (c) energy from waste and biomass, (d) energy efficient products, (e) low carbon services, and (f) low emission vehicles and infrastructure within which the following 17 low carbon sectors are defined: (a) offshore wind, onshore wind, solar photovoltaic, hydropower, other renewable electricity, carbon capture and storage and nuclear; (b) renewable heat, renewable CHP; (c) bioenergy, alternative fuels; (d) energy efficient lighting, other energy efficient products, energy monitoring, saving or control systems; (e) low carbon financial and advisory systems; (f) low emission vehicles and infrastructure, fuel cells and energy storage systems

related to minimising the impact of natural hazards and those related to the extraction, mobilisation and exploitation of natural resources are also excluded” (ONS, 2017a: 2). National statistics agencies therefore do not collect data on adaptation goods and services.

This clearly presents an issue in responding to the Committee on Climate Change’s recommendation for improving the evidence base underpinning our understanding of the opportunities that businesses will face from a changing climate.

2 Studies of the Adaptation & Resilience (Climate Change) (A&RCC) Economy

While there have been several qualitative studies of the A&RCC economy (CCC, 2017 (Chapter 6); Ricardo, 2017; Acclimatise, 2015; PwC, 2013; GHK, 2010), there is very limited quantitative evidence of the scope and scale of those opportunities. The following sections explore attempts to provide that evidence.

2.1 Economy-wide studies

The 2009 paper analysing the industry for low carbon goods and services (Sharp, 2009) is the starting point for a method subsequently developed by kMatrix to assess the market for adaptation goods and services, or the Adaptation and Resilience (Climate Change) (A&RCC) sector as described there.

Four key measures were defined:

- Sales: turnover by sub-sector at all levels within postcode sets. Only sales that can be attributed to the product lines are included (apportionment).
- Companies: operating directly and indirectly in the sector; a 20% threshold is established as the floor for contribution, below which companies are not considered to contribute to the economy.
- Employment
- Market growth projections

Data are ‘triangulated’ across at least 7 different sources relevant to any given ‘product line’ to establish a minimum confidence level of 80%.

From 2011, market assessments commissioned by BIS started to include the ‘adaptation economy’. This was considered separately from the LCEGS assessments as a series of reports on *Adaptation and Resilience (Climate Change) (A&RCC)*. The pilot study aimed “to identify and measure a defined set of environmental Adaptation and Resilience activities, in relation to Climate Change, (A&RCC) in the UK economy, by drawing on the K-Matrix dataset for Low Carbon Environmental Goods and Services (LCEGS)” (BIS, 2011).

It focused initially on eight A&RCC activities identified by DEFRA although early modelling resulted in a slightly different configuration of nine ‘revised DEFRA categories’ (*ibid*: 7-8 (Figure 2)) :

- Construction and retrofit
- Transport infrastructure and logistics resilience
- Architectural
- Enviro finance
- Finance, investment and insurance
- Sustainable drainage and water management

- Risk management and business continuity
- Climate change management
- Water irrigation and footprinting

Some of these were new to the LCEGS sector and some required a reassessment of the A&RCC content of existing LCEGS activities.

The 'new' A&RCC activities, as distinct from the earlier LCEGS activities, resulted in one hundred and sixty three (163) new activities whose data now had to be calculated from new sources (*ibid*, Appendix A: 29-34).

The study also attempted to estimate the A&RCC content of the existing 2,490 activities from the earlier LCEGS Report (Sharp, 2009). The inclusion criteria were included in Appendix B.

The resulting market assessment overlapped LCEGS sales by 67%. This was considered an 'unhelpful outcome' that overstated the A&RCC activities by including what were undoubtedly non-A&RCC activities.

The authors suggested that more detailed analysis was probably required as it is often difficult to assess what a product is intended to be used for as opposed to what it actually is. They ran a limited sensitivity test for a sample of A&RCC activities disaggregated to a lower level of SIC classification and confirmed that this would improve the accuracy of the assessment. They noted that this more detailed analysis would require access to additional data sources (mostly procurement data), and recognised that these are generally not as widely available as sales data.

The Report for 2010/11 (BIS, 2012) built on the 2009/10 pilot method and disaggregated activities to a lower level, providing a better understanding of the intent or use or purpose of each product, supplemented by additional desk research, if required. The data were then aggregated back up for analysis. This process created many more 'product lines' of activity data. Disaggregating the original 163 activities by just one additional level created 100 new sub-divisions alone. Overall the new 'research data set' now included around 18,000 lines of activity data.

For analysis purposes, product content was categorised as either:

- response to climate change;
- responses to general environmental/ecological disasters;
- responses to general environmental policies and targets;
- general maintenance ;
- traditional (non climate change) applications; and/or
- other non-climate change services.

This categorisation was then used to establish a baseline of A&RCC activity; global A&RCC activity was estimated at £66Bn for 2010/11.

The Report for 2011/12 (BIS, 2013b) was based on the same general method as the 2010/11 Report but used the disaggregation/re-aggregation approach to separate out climate-related goods and services from 'other' A&R products.

UK A&RCC sales for 2011/12 were estimated at ~£2.1Bn, a 3.1% share of global sales for that year.

A regional analysis was also provided for the first time. A&RCC sales in Scotland (£198m) ranked 4th (of 12) in the UK behind London, the Southeast and the East of England; 4th for employment (1,901) behind the same regions; and 6th for the number of companies operating in the 'sector' (129) behind London, the Southeast, East, West Midlands and Northwest of England.

Then the 5th IPCC assessment report was published in 2014 (IPCC, 2014). Within it the A&RCC Economy was now interpreted to mean: *measurable economic activities that can be attributed with*

some confidence as a reaction or planned response to extreme weather. The key products contributing to economic activity now included: systems that warn people of impending disasters; changes in land use planning; sustainable land management; ecosystem management; improvements in health surveillance; water supplies and drainage systems; development and enforcement of building codes; and better education/awareness

Different options were presented for 'organising the evidence base': by threat type (Chapters 3-7); by geography, including urban/rural (Chapters 8 and 9); by economic sector (Chapter 10).

The influence of AR5 WGII is very apparent in the kMatrix analyses that followed its publication. In their 2015 assessment of the A&RCC Economy for London (kMatrix, 2014a), the 9 'revised DEFRA categories' used in the earlier reports were superseded (and absorbed) by 10 core areas derived from IPCC AR5 WGII's sectoral analysis of hazards and risks:

- Agriculture and forestry
- Built environment
- Disaster preparedness
- Energy
- Health
- ICT
- Natural environment
- Professional services
- Transport
- Water

Activities in each of these areas covered goods and services addressing the full range of hazards exacerbated by climate change: sea level rise and coastal flooding and storm surges; food insecurity and the breakdown of food systems linked to warming, drought and precipitation variability; inland flooding and the threat to large urban populations; insufficient access to drinking and irrigation water in rural areas and reduced agricultural productivity; systemic risks affecting infrastructure electricity, water supply, health and emergency services; and health risks due to extreme heat, air pollution and disease.

The 2014 kMatrix report separated A&RCC from the general market for A&R (Adaptation and Resilience) goods and services. An attempt to further separate adaptation products from resilience products was abandoned as a result of low confidence in the quality of the separated data. Nonetheless the breakout of the A&RCC sub-sectors from overall economy as a whole is informative, see Table 1.¹¹

¹¹ It is worth emphasising that the quality of the data in the 2014 report has not been independently assessed and, given that the report remains unpublished, the data should be taken as indicative rather than definitive.

Table 1: estimates of the scope and size of the A&RCC Economy (2012/13) (kMatrix, 2014a):

	A&R	A&RCC	A&RCC Companies	A&RCC Employment
<i>Global</i>	£1.4Tn	£206Bn	132,000	3.3m
<i>UK</i>	£44Bn	£6.3Bn	4,080	76,000
<i>London</i>	£6.9Bn	£897m	508	9,707
<i>Scotland</i>	n/a	£563m	344	6,472
<i>Glasgow</i>	£191m	£24m	67	254

Projects in London (2015) and Glasgow City Region (2018)¹² have continued to commission kMatrix to scope and size their regional Adaptation Economies. In 2016, kMatrix worked with *C40 Cities* to provide a similar assessment for 7 cities in the Green Growth Network.¹³

A similar method has been used in profiling other sectors. A much fuller elaboration of the kMatrix method is provided for the security sector for example in *Methodology for UKTI/ DSO Security Research 2014* (kMatrix, 2014b).

While kMatrix's profiling approach is the most widely adopted, other methods have been used.

2.2 Sampling studies

2.2.1 Open sampling frame

The first Climate Change Risk Assessment published by DEFRA in 2012 had also noted that “a changing climate in the UK may provide opportunities for agriculture and other businesses, although not outweighing the threats” (DEFRA, 2012).

Following the approach that had been used in the Low Carbon and Environmental Goods Sector (LCEGS), DEFRA commissioned the Office for National Statistics (ONS) to explore the feasibility of developing a Climate Change Survey (CCS), similar to the LCRE Survey being run for BEIS but for the A&RCC Economy. Its aim was to determine the impact of climate change on the economy in terms of costs and opportunities in the market for goods and services, “with the express purpose of assessing the feasibility of satisfying this domestic policy demand through the creation of a new survey” (ONS, 2015).

The ONS took a top down approach to identify a population drawn from the ONS IDBR sampling frame of 2.7 million UK businesses. These were then ‘stratified’, splitting the target population into different non-overlapping groups (‘strata’) which could then be sampled from independently. A minimum sample size of 5 was used within each stratum for robust results, resulting in an estimated overall sample size in the range 20,000 - 40,000, depending on which survey design was chosen.

¹² Climate Ready Clyde www.sniffer.org.uk/climatereadyclide includes 8 Local Authorities, NHS Greater Glasgow and Clyde, University of Glasgow, Strathclyde Partnership for Transport. This work is forthcoming having only just been funded by Scottish Government.

¹³ *New C40 Project to Measure Cities' Green Economic Success*: www.c40.org/blog_posts/new-c40-project-to-measure-cities-green-economic-success. The report resulting from this work has not been found in the public domain.

Four different survey designs were evaluated ranging from a whole economy approach to a focus on specific sectors which had been identified in different literatures as being more (opportunities) or less (risks) likely to benefit from a changing climate. Based on early feedback from stakeholder groups, a draft questionnaire was produced which was then tested with different business sectors. This provided an initial view of what the data collection instrument might look like and where additional development and testing would be required.

The feasibility study made 10 recommendations. A number were technical in nature relating to the way the data was collected and extrapolated - sample size, imputation methods, etc. Some were procedural, reflecting the ONS code of practice to run a formal consultation on any proposal for the creation of a new statistical product as well as the need for a pilot study. But, the study also found that “there were issues in how respondents differentiated between adaptation for climate change and everyday weather”, and “in how adaptation products and opportunities [were] defined”. As a result of these findings, the ONS Data Collection Methodology indicated that the RAG (Red, Amber, Green) status of the questionnaire should be considered *amber-red*: the validity of the producer (opportunities) and consumer (costs) questions needed further investigation.

ONS therefore launched a second consultation on these issues to see if they could be overcome (ONS, 2016). Feedback on the draft questionnaire was requested from stakeholders in business, policy, academia and ‘other’ (*ibid*, Annex A). It became clear that businesses were having difficulty providing the information, particularly the quantified data, requested in the draft questionnaire.

Some of the consultation respondents were identified as potential partners (Annex A) with whom ONS may collaborate to help further develop the survey, as well as some additional external data sources that might be used in order to meet some of the user requirements outlined (cf. CDP survey¹⁴). Overall though, the consultation concluded that: “Resource allowing, ONS will continue to review user requirements whilst assessing the quality of available data and will have more detailed discussions with potential data providers. These actions will take precedent (*sic*) over the pilot survey recommendation within the feasibility study.” In fact, there was no commitment by ONS or DEFRA to progress the pilot or undertake full survey and the initiative has since stalled.

2.2.2 Proprietary sampling frame

Ricardo was commissioned by the Committee on Climate Change (CCC) to update estimates of the opportunities presented by the transition to a low carbon economy (Ricardo, 2017). Their approach, which is similar to those discussed in §1.2 above, updates an earlier baseline (TBR, 2015) using statistics published subsequently in other studies:

- The Low Carbon and Renewable Energy (LCRE) Economy survey undertaken by ONS for BEIS (ONS, 2017c)
- The *size and performance of the low carbon economy* report, prepared by TBR and published by BIS/DECC in 2015 (TBR, 2015)
- A range of sector based data published by trade associations and based on surveys of their members.
- Statistics prepared by Innovas/kMatrix (Sharp, 2009; Innovas 2010, 2011, kMatrix 2011, 2012)

They discounted Innovas/kMatrix as a closed method and focussed instead on the first three, providing an assessment of strengths and weaknesses as the basis for the CCC’s evaluation (Ricardo, 2017: Appendix §A1A)

The authors note though that here too adaptation products were excluded. The work undertaken by kMatrix and others described above (§2.1) was dismissed here too as a closed method. The report states that a new approach would be required: “[a]s there were no existing estimates for the sector,

¹⁴ CDP Questionnaire: www.cdp.net/en/guidance

work had to be undertaken *de novo*, so the data must be considered less robust than those presented above (*referring to the LCEGS study*)” (*ibid*: §A1B.1).

As an initial trial Ricardo undertook an analysis to investigate the ‘Adaptation’ sector, which included “the design, production, installation and maintenance of products (sic) and services aimed at adapting to the effects of climate change”.

Their approach used key word search of firms operating in five thematic ‘groups’ (*ibid*: Table §A1B.1):

- Building adaptation
- Business mitigation and management
- Climate event planning and response
- Flood mitigation and management
- Public realm adaptation
- Each was further segmented into one or more ‘keyword sectors’.

Additionally, the analysis included firms known (anecdotally) to produce climate change adaptation goods and services but who were not identified in the keyword search, presumably as this area of activity represented only a (relatively small) proportion of their work. The SIC codes covering these firms were also now included in the analysis. The products of firms operating in these *Sections* were then analysed to establish the extent to which they had been developed to address climate change adaptation and apportioned accordingly in estimating market value. Three additional groups in SIC Section M (Professional, Scientific and Technical Activities) were included:

- Engineering related scientific and technical consulting services (SIC: 71.12/2)
- Other engineering activities (SIC: 71.12/9)
- Other research and experimental development on natural sciences and engineering (SIC: 72.19)

The combined dataset contained 22,444 records:

- 3,309 from the keyword search of which 2,748 were in air conditioning and ventilation (sub-sectors of building adaptation)
- 18,935 in the ‘SIC based’ extract of which 11,510 were in engineering related scientific and technical consulting activities.

Apportionment was based on Ricardo’s estimates of the level of contribution that A&RCC activities might make to the business overall: High (5%-7%), Medium (3% - 5%) and Low (1% - 2%) “coefficients” were provided.

Ricardo (self) assessed their results to be of the correct order of magnitude by calibrating them against the UK Government’s stated spend on flood defences and mitigation in the 2016 Autumn Statement. Their estimate of the size of the economy in comparison with other estimates is shown in Table 2.

Table 2: estimates of the scope and scale of the A&RCC economy for the UK

	Coefficient	Employees	Turnover (£Bn)	GVA (£Bn)	Companies
Ricardo (2017)	Low	9,861	1.3	0.5	
	Medium	16,084	2.3	0.9	
	High	20,244	2.95	1.2	
BIS (Innovas/kMatrix, 2013) Revised DEFRA activities		19,864	2.1		1,486
LCCP (kMatrix, 2014) IPCC WGII AR5 activities		76,347	6.3		4,080

2.2.3 Selective sampling frame

In 2017, Scottish Enterprise commissioned AECOM to provide an assessment of the economic impact of climate change on the key sectors of the Scottish economy (Scottish Government, 2015). Like several other studies (GHK, 2010) this work considered a subset of the whole economy and focused only on those sectors of the economy that Scottish Enterprise is responsible for developing.

The findings have yet to be published but in a presentation at a 2020 Climate Group meeting in February 2018, the Scottish Enterprise's Strategy Partner¹⁵ provided a summary of the findings from their survey of business perceptions of risks and opportunities in each sector:

Sustainable Tourism: has adopted what is primarily a risk management perspective, particularly in its consideration of supply chain vulnerabilities.

Finance and Business Services: identified opportunities in disaster insurance and investment in climate ready infrastructure.

Food and Drink: opportunities were identified for new crops, new fish stocks, and a longer growing season.

Construction: opportunities were identified in flood management engineering and low carbon housing (cf adaptive building) which is an 'enabling sector' for the Scottish economy.

Energy: opportunities were identified for products addressing energy resilience, renewables and energy storage, carbon capture and storage, cooling and arctic drilling

Digital Economy: another enabling sector for the Scottish economy with opportunities identified particularly in applications of sensors (Internet of Things (IoT)) and data analytics.

No details of either the method or the survey were made available during the presentation.

¹⁵ Lesley Frostick, Strategy Partner, Scottish Enterprise. 0300 013 3317 | lesley.frostick@scotent.co.uk

The principal objective of this study appears to have been to provide an estimate of the value of exports of climate-related goods and services produced within the Scottish growth sectors.

The report will be published on Scottish Enterprise 'Evaluations' in due course.¹⁶

3 Lessons learned

Based on these studies, the following observations are made:

- **Purpose:** A&RCC studies have been used to provide a baseline of the value of adaptation and resilience goods and services to the UK economy. The last baseline was calculated for the 2012/13 and at that time its value was around 0.4% of GDP. However that baseline is now six years out of date. The decision on the design of any new study will need to include a consideration of purpose: is the valuation to be used to simply understand the market potential in the Scottish context or will it be aligned now or in the future with the UK Environmental Account and therefore follow the UNSEEA-CF 2012 standard.
- **Scope and scale:** economy-wide methods provide comprehensive coverage of the 10 IPCC core activities will be required, disaggregated to a level of detail equivalent of a 7-digit SIC code to determine the use, purpose or intent of products (kMatrix, 2014). Selective sampling methods on the other hand provide order of magnitude estimates based on limited scope (and scale) (Ricardo, 2017).
- **Data quality is difficult to verify.** The studies use many data sources. The kMatrix study of the London Adaptation Economy for example cites 960 (kMatrix, 2014a); some of these are in the public domain, many are proprietary. By contrast ONS data quality is consistently high even for 'green economy' statistics that have 'experimental' status.
- **Analytical capability:** most of the methods used in these studies simply provide quantitative analyses with little interpretation. The analysis of sub-sectors contributing to the A&RCC Economy for example presents the relative sectoral strengths without any discussion of changes in the mix of products within those sectors. Developing a qualitative narrative would be useful although this depends to some extent on a consistent method (activities and measures) and availability of a time series.
- Wide-spread adoption of a particular method enables comparative benchmarking at different scale (national, regional and local). For A&RCC, the method continues to evolve. Changes to the range of activities contributing to the economy in line with IPCC AR5, for example, means that these benchmarks currently should be considered indicative rather than definitive.
- Updates to estimates of the value of the A&RCC Economy could use a survey of a statistically representative sample of companies operating in that economy. This would need to take account of the burden on the target group and the costs of analysing the results.
- Prior to any surveying, the A&RCC Economy will need scoping so that a sampling frame can be used to identify the target group. The choice of sampling frame is important. The ONS IDBR, for example, is a verified national database, which is subject to statistical disclosure controls. While this would not limit the level of detail used in any analysis, it would likely limit the level of detail that could be published. The TCR frame developed by TBR/OrtusER on the other hand is "readily available and can be used to provide estimates into the future" (§4.1 below)
- If this approach is adopted, a consultation will be required to provide a rigorous definition of what adaptation and resilience goods and services actually are.

¹⁶ Scottish Enterprise evaluations online: www.evaluationsonline.org.uk/evaluations/Index.do

4 Data sources

4.1 Primary research

The 2010 ONS study notes that “In line with the UK Statistics Authority Code of Practice for Official Statistics existing data sources and estimation techniques must be evaluated before considering a new survey to ensure proportionate burden on suppliers. Additionally, official data sources should be considered ahead of others. This applies to the measurement of the environmental goods and services sector and is a common approach internationally”¹⁷ (Livesey, 2010).

Some of the primary research cited above *has* created new surveys to establish the scope and size of the market for adaptation goods and services, specifically climate-related products (TBR, 2015, ONS, 2015).

These have used a sampling frame to help segment the population in a statistically representative way. The ONS Inter-departmental Business Register (IDBR)¹⁸ is the preferred frame. However, access to this data is subject to statistical disclosure control although it is available to some researchers if authorised by the *Microdata Release Panel*.¹⁹ Other sampling frames are available.

The Trends Central Resource (TCR) dataset, for example, used in scoping the low carbon and environmental goods sector could provide an alternative sampling frame for the A&RCC sector (TBR, 2015: Appendix V). TCR contains data on 5 million companies going back to the 1970s, including employment, turnover and GVA with a seamless 18-year time series starting in 2000. Unlike IDBR “TBR’s data are readily available and can be used to provide estimates into the future” (Ricardo, 2017: §A1A.2).

However, identifying the data sources used to populate these datasets is not always straightforward. For the TBR study, for example, over 130 data sources were apparently used to identify companies operating in the low carbon sector (TBR, 2015: Appendix 3, 82). They are not listed.

4.2 Secondary research

For secondary research, an even broader and more diverse range of data sources is required. The selection of specific datasets depends on the analytic depth and breadth required: local, regional, national and international comparators for example. Again identifying these data sources is far from easy.

In looking at the 2011 research underpinning the Scottish LCEGS market, the method described by Innovas includes a note that “a full list of data sources would be delivered at the end of the study” (Innovas, 2011: 93) together with an interactive analysis tool (*ibid*: 18). It would be useful to see whether these are still available. The LCEGS 2009/10 Report from BIS similarly notes that the data sources used were included in an appendix although this was not included with the report. None of these are readily available elsewhere in the public domain. On the other hand, the industry analysis of the low carbon and environmental goods sector does list all 720 data sources used in identifying the 2,490 activities supporting the study (Sharp, 2009: Appendix 2, 104-121); so too does the annex to the UK Environmental Account 2010-2014 for the 20 activities identified there. (ONS, 2017b).

For the A&RCC market, the BIS Report for 2009/10 (BIS, 2011) references the 2009/10 LCEGS dataset; the Report for 2010/11 (BIS, 2012) references the 2010/11 LCEGS dataset; and the Report for 2011/12 (BIS, 2013b) references the 2011/12 LCEGS Report. The Table of Contents for the 2009/10 and 2010/11 LCEGS reports shows data sources in an appendix, but again those appendices

¹⁷ UK Statistics Authority Code of Practice for Official Statistics: www.statisticsauthority.gov.uk/assessment/code-of-practice/index.html

¹⁸ IDBR: www.ons.gov.uk/aboutus/whatwedo/paidservices/interdepartmentalbusinessregisteridbr

¹⁹ Microdata Release Panel: www.ons.gov.uk/aboutus/whatwedo/statistics/requestingstatistics/approvedresearcherscheme#microdata-release-panel-mrp

are not included in either report. The 2011/12 LCEGS report simply updates the data on the 2010/11 report and provides no further detail on the data sources used. It does though indicate that kMatrix *proprietary* databases are used (together with many other data sources) to create the dataset on which the analysis is based (BIS, 2013a: §2.4).

This is perhaps unsurprising as these datasets are expensive to collate and effectively constitute each consultancy's comparative advantage.

The unpublished kMatrix report on London's Adaptation Economy (kMatrix, 2015) does include around 960 'selected' data sources that were used to populate the dataset used in their analysis of the 10 sector A&RCC (Adaptation) Economy (Annex B)²⁰. Source selection and management is included in Annex C.

5 Conclusions & recommendations

The A&RCC Economy involves companies operating across multiple, vertical industry *Sections, Divisions* and *Groups* (ONS, 2007). To measure that economy, to create a baseline of its economic value, requires it first be scoped to include those products whose intent, purpose or use is help adapt or become resilient to climate-related hazards; something which is not always possible using just a description of what a product is. Data on the companies providing those products can then be mapped accurately from an appropriate set of data sources to the resulting 'product lines' before aggregating back up to a level appropriate to the analysis that is required. This requires a method that can disaggregate product descriptions to a level that is sufficiently detailed for that intent to become evident.

Qualitative and quantitative methods for profiling the A&RCC Economy have been reviewed. To a greater or lesser extent, they all draw on similar methods that were developed previously to profile two related segments of the 'green economy': the *Environmental Goods and Services Sector* and the *Low Carbon and Renewable Energy Economy*. A number of observations have been made in guiding any research that seeks to update the most recent (2012/13) baseline (§3).

The A&RCC baseline will need to be updated periodically. The timetable for doing so would correspond to the timetable of the Scottish Adaptation Programme: annual progress reports, biennial independent assessments, five yearly SCCAP publication cycle.

There are two ways of providing that update: a refresh of the data sources used in establishing the baseline or a survey of a statistically representative sample of companies operating in the A&RCC Economy. The former would be functional and begin to establish a time series; the latter has the potential to provide much richer insight into the details of the economy. However, the ONS Feasibility Study found that a rigorous definition of products contributing to the A&RCC Economy would be required to progress any surveying approach (ONS 2016, 2017).

The baseline would provide evidence to inform the second Scottish Climate Change Adaptation Programme (2019). The decision on the method supporting subsequent updates is to some extent contingent on discussions with ONS, DEFRA and the Committee on Climate Change for future research.

Consequently, the following recommendations are made in responding to the call for evidence made in the Adaptation Sub-Committee's independent assessment of the Scottish Climate Change Adaptation Programme (ASC, 2016) and the UK Climate Change Risk Assessment (CCC, 2017):

- 1. To tender a baseline assessment of the Scottish A&RCC Economy.** In order for the assessment to incorporate the learning from the earlier A&RCC work and similar analyses, we recommend that the baseline is created with the following characteristics:

²⁰ A breakdown of the Adaptation Economy Product and Service (sic) categories to Levels 2, 3 and 4 is included also in Annex A.

- a. **Variables:** key measures
 - ONS and Scottish Business Statistics use turnover, employment and the number of companies (ONS, 2017c; Scottish Government 2017)
- b. **Activities:** to be included in the study
 - IPCC WGII AR5 activities are a superset of the 'revised DEFRA' activities used in the early A&RCC studies and are preferred in scoping the A&RCC economy.
- c. **Scope:** inclusion criteria for the supply chain
 - Indirect (supply chain) producers contribute to the A&RCC economy and are generally included in economic impact assessments where their contribution to a sector is significant (>20%)
- d. **Product inclusion criteria:** the intent, use or purpose of adaptation goods and services and the (climate-related) hazards they address
 - The classification scheme needs to be (able to be) disaggregated to a level where the intent, use or purpose of a product can be determined. This may be lower than the level at which analysis usually takes place.
- e. **Apportionment:** for companies only partially operating in the A&RCC economy
 - A minimum threshold (floor) that at least 20% of company turnover has to be derived from the A&RCC economy for the company to be included in the economy would be in line with the studies cited below.
Only the A&RCC specific turnover should be included in value estimates
- f. **Data:** availability, quality and maintenance
 - A fully referenced list of data sources used in developing the baseline should be available to enable transparency.
A regular schedule for updating the underlying datasets will be required. Different timetables need to be considered in line with SCCAP milestones: annual progress reports, biennial independent assessments, 5-yearly SCCAP publication cycle.
An open data interface would enable additional analyses to take place over and above that provided by the supplier.
- g. **Accuracy:** confidence factors
 - A minimum confidence factor for data should be established for each stage of dis/aggregation; 85% is standard in the studies cited below.
- h. **Alignment:** of the method with ONS, UN SEEA accounting principles
 - By including indirect producers in the economy as outlined at (c) above the baseline will not conform with the UNSEEA-CF (2012) standard or the generally agreed principles governing the UK Environmental Account maintained by ONS.
Options to provide separate estimates of the economy for direct and indirect producers should be explored.
- i. **Analytical capability:** comparators; breadth of benchmarking; depth of analysis (including the separation of climate-related products from the broader Adaptation and Resilience (A&R) economy).
 - This study has not considered the resource implications of different analytical capabilities. However, we suggest:
 - a breakdown and comparison between the 32 Scottish Local Authorities would be useful

- comparisons with other UK, EU or global countries, regions or cities would also be useful, although this would need normalising to be very meaningful. Normalisation factors might include: GVA (per head), working population, company numbers by size and activity, etc.

2. To develop a method to support periodic updates to the baseline dataset to enable year-on-year comparisons and start to develop a time series for the A&RCC Economy.

The baseline dataset could be used to stratify a sampling frame, providing a statistically representative sample of economic producers operating in the A&RCC Economy who could then be regularly surveyed.

A survey has the potential to provide much richer insight into the details of the A&RCC Economy. It would though need to take account of the issues raised in the consultation following the ONS Feasibility Study for a Climate Change Survey (§2.2.1) (ONS, 2015, 2016).

Where a survey-based approach is judged to be infeasible for reasons of cost, burden or inherent limitations in the design, a regular update directly to the baseline dataset could be explored as outlined in point (f) above.

Finally, there are other projects taking place in Scotland that have similar objectives to the work described here, albeit at different scale. The regional assessment of the adaptation economy of the Glasgow City Region and Scottish Enterprise's assessment of the risks and opportunities for the six key growth sectors are two; there may be others. Any future research should consider potential synergies with these projects.

6 References

1. Acclimatise (2015) *Business Opportunities in a Changing Climate*. Environment Agency; available at: www.acclimatise.uk.com/wp-content/uploads/2017/11/EA-report.pdf
2. ASC (2016) *Scottish Climate Change Adaptation Programme: An independent assessment for the Scottish Parliament*. Committee on Climate Change, September 2016; available at: www.theccc.org.uk/wp-content/uploads/2016/09/Scottish-Climate-Change-Adaptation-Programme-An-independent-assessment-CCC-September-2016.pdf
3. BIS (2011) *Adaptation and Resilience (Climate Change) (A&RCC): Report for 2009/10*. kMatrix for BIS; available at: webarchive.nationalarchives.gov.uk/20120708235148/http://www.bis.gov.uk/assets/biscore/business-sectors/docs/a/11-1033-adaptation-and-resilience-climate-change-2009-10.pdf
4. BIS (2012) *Adaptation and Resilience Climate Change (A&RCC): Report for 2010/11*. kMatrix for BIS; available at: webarchive.nationalarchives.gov.uk/20120708222449/http://www.bis.gov.uk/assets/biscore/business-sectors/docs/a/12-p144-adaptation-and-resilience-climate-change-2010-11.pdf
5. BIS (2013a) *Low Carbon Environmental Goods and Services (LCEGS): Report for 2011/12*. BIS; available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/224068/bis-13-p143-low-carbon-and-environmental-goods-and-services-report-2011-12.pdf
6. BIS (2013b) *Adaptation and Resilience Climate Change (A&RCC): Report for 2011/12*. BIS; available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/224070/bis-13-p144-adaptation-and-resilience-climate-change-report-2011-12.pdf
7. CCC (2017) *UK climate change risk assessment 2017 Evidence Report*. Committee on Climate Change, 2016; available at: www.theccc.org.uk/UK-climate-change-risk-assessment-2017
8. DEFRA (2012) *UK Climate Change Risk Assessment: Government Report*. HM Government; available at: www.gov.uk/government/publications/uk-climate-change-risk-assessment-government-report
9. European Commission (2009a) *The Environmental Goods and Services Sector Methodologies and Working Papers*; available at: http://ec.europa.eu/eurostat/portal/page/portal/product_details/publication?p_product_code=KS-RA-09-012
10. European Commission (2009b), *EGSS Trial Data Collection 2009*; available at: www.eurostat.ec.europa.eu/portal/environmental_accounts/methodology/data_collections
11. GHK (2010) *Opportunities for UK Business from Climate Change Adaptation*. DEFRA GA0403; available at: randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17072#RelatedDocuments
12. Innovas (2010) *Low Carbon and Environmental Goods and Services: An Industry Analysis Update for 2008/09*; available at: webarchive.nationalarchives.gov.uk/20120708235150/http://www.bis.gov.uk/assets/biscore/business-sectors/docs/10-795-low-carbon-environmental-goods-analysis-update-08-09.pdf
13. Innovas (2011) *Scotland Low Carbon and Environmental Goods and Services: Sector Study*. Scottish Government; available at: www.gov.scot/resource/doc/344829/0114756.pdf

14. IPCC (2014) *IPCC WGII AR5: Impacts, Adaptation and Vulnerability*. IPCC; available at: www.ipcc.ch/report/ar5/wg2
15. kMatrix (2011) *Low carbon and Environmental Goods and Services (LCEGS): Report for 2009/10*. BIS; available at: webarchive.nationalarchives.gov.uk/20120708235142/http://www.bis.gov.uk/assets/biscore/business-sectors/docs/l/11-992x-low-carbon-and-environmental-goods-and-services-2009-10.pdf
16. kMatrix (2012) *Low Carbon Environmental Goods and Services (LCEGS): Report for 2010/11*. BIS; available at: webarchive.nationalarchives.gov.uk/20120708235139/http://www.bis.gov.uk/assets/biscore/business-sectors/docs/l/12-p143-low-carbon-environmental-goods-and-services-2010-11.pdf
17. kMatrix & Gyron LLP (2013a) *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Greater Manchester*. ENWORKS; available at: [enworks.com/resources/Economic potential of LCEGS Sector in Greater Manchester 1.pdf](http://enworks.com/resources/Economic%20potential%20of%20LCEGS%20Sector%20in%20Greater%20Manchester%201.pdf)
18. kMatrix & Gyron LLP (2013b) *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Cumbria*. ENWORKS; available at: [enworks.com/resources/LCEGS Market Intel Report for Cumbria LEP Final\(1\).pdf](http://enworks.com/resources/LCEGS%20Market%20Intel%20Report%20for%20Cumbria%20LEP%20Final(1).pdf)
19. kMatrix & Gyron LLP (2013c) *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Liverpool City Region*; available at: www.liverpoollep.org/wp-content/uploads/2015/06/wpid-lcegs-summary-report-for-lcr-11-2013.pdf
20. kMatrix & Gyron (2014) *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Liverpool City Region*. ENWORKS; available at: www.liverpoollep.org/wp-content/uploads/2015/06/wpid-final-lcegs-market-intel-report-for-lcr-lep-10-2013.pdf
21. kMatrix (2014a) London's Adaptation Economy 2012/13. unpublished.
22. kMatrix (2014b) *Methodology for UKTI/ DSO Security Research 2014*; available at: [www.gov.uk/government/uploads/system/uploads/attachment_data/file/327683/KMatrix_Security Stats Methodology for 2013.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/327683/KMatrix_Security_Stats_Methodology_for_2013.pdf)
23. kMatrix (2015) *London's Low Carbon and Environmental Goods and Services: Updated Report*; available at: www.london.gov.uk/sites/default/files/london_low_carbon_market_snapshot_-_update_report_2015.pdf
24. Livesey, D. (2010) Measuring the environmental goods and services sector. *Economic & Labour Market Review* 4(12):45-58. <https://doi.org/10.1057/elmr.2010.165>
25. Livesey, D. (2011) Methodological Developments to the UK Environmental Accounts. *Economic & Labour Market Review* 5(7):113-122. <https://doi.org/10.1057/elmr.2011.65>
26. OECD (1996) *The Global Environmental Goods and Services Industry*; available at: www.oecd.org/industry/ind/2090577.pdf
27. ONS (2007) *UK SIC 2007*; available at: www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities/uksic2007
28. ONS (2014) Improvements to the UK Environmental Account. ONS.
29. ONS (2015) *Climate Change Survey. Feasibility Study*. ONS; available at: www.ons.gov.uk/aboutus/whatwedo/statistics/consultationsandsurveys/allconsultationsandsurveys/climatechangesurveyconsultation
30. ONS (2016) *Response to the ONS consultation on the Climate Change Survey*. ONS; available at:

www.ons.gov.uk/aboutus/whatwedo/statistics/consultationsandsurveys/allconsultationsandsurveys/climatechangesurveyconsultation

31. ONS (2017a) *UK environmental goods & services sector 2010-2014*; available at: www.ons.gov.uk/economy/environmentalaccounts/bulletins/ukenvironmentalaccounts/2010to2014
32. ONS (2017b) *Environmental goods and services sector (EGSS) methodology annex*: www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalgoodsandservicessectoregssmethodologyannex
33. ONS (2017c) *UK Business: activity, size & location*; available at: www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/ukbusinessactivitysizeandlocation/2017
34. ONS (2018) *UK Environmental Accounts: Low Carbon and Renewable Energy Economy Survey: 2016 final estimates* available at: <https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2016>
35. PwC (2013) *International threats and opportunities of climate change for the UK*. PwC; available at: pwc.blogs.com/files/international-threats-and-opportunities-of-climate-change-to-the-uk.pdf
36. Ricardo (2017) *UK Business opportunities of moving to a low carbon economy*. Committee on Climate Change; available at: www.theccc.org.uk/wp-content/uploads/2017/03/ED10039-CCC-UK-Bus-Opportunities-Draft-Final-Report-V7.pdf
37. Scottish Government (2015) *Scotland's Economic Strategy (2015)*: beta.gov.scot/publications/scotlands-economic-strategy/
38. Scottish Government (2017) *Scottish Annual Business Statistics*; available at: www.gov.scot/Resource/0052/00523940.pdf; see also *Businesses in Scotland*: www.gov.scot/Topics/Statistics/Browse/Business/Corporate
39. Selwyn, J. and Leverett, B. (2006) *Emerging Markets in the Environmental Sector*. UKCEED; available at: www.codexx.com/pdf/DTI%20Emerging%20Markets%20Report%20Final%20Nov%202006.pdf
40. Sharp, J. (2009) *Low Carbon and Environmental Goods and Services: An Industry Analysis* Innovas for BERR; available at: webarchive.nationalarchives.gov.uk/20100512230841/http://www.bis.gov.uk/files/file50253.pdf
41. TBR (2015) *The Size & Performance of the UK Low Carbon Economy: report 2010 to 2013*; available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/416240/bis-15-206-size-and-performance-of-uk-low-carbon-economy.pdf
42. Titley, B., Williams, S., Anastasi, E. and Gill, H. (2009) *Towards a Low Carbon Economy - economic analysis and evidence for a low carbon industrial strategy*. Department for Business, Innovation & Skills (BIS) Economics Paper No.1; available at: webarchive.nationalarchives.gov.uk/+http://www.bis.gov.uk/files/file52165.pdf
43. UN (2014) *UN System of Environmental Accounting 2012 - Central Framework*; available at unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf

7 Bibliography

1. Brueton, A. (1999) ONS Plans for the 1999 and 2000 Blue and Pink Books. *Economic Trends* No. 546; available at:

webarchive.nationalarchives.gov.uk/20151014012431/http://www.ons.gov.uk/ons/rel/elmr/economic-trends--discontinued-/no--546--may-1999/index.html (discontinued).

2. Eurostat (2016) *The Environmental Goods and Services Sector. A data collection handbook*. EU; available at: ec.europa.eu/eurostat/documents/3859598/7700432/KS-GQ-16-008-EN-N.pdf/f4965221-2ef0-4926-b3de-28eb4a5faf47
3. Georgeson, L., Maslin, M., Poessinouw, M. and Howard, S. (2016) Adaptation responses to climate change differ between global megacities. *Nature Climate Change* 6: 584-588 doi: 10.1038/NCLIMATE2944
4. Georgeson, L., Maslin, M. and Poessinouw, M. (2017) Global disparity in the supply of commercial weather and climate information services. *Science Advances* 3(5) doi: 10.1126/sciadv.1602632
5. Maslin, M. and Poessinouw, M. (2012) Emergence of the carbon-market intelligence sector. *Nature Climate Change* 2: 300-302.
6. Georgeson, L. and Maslin, M. (2017) The global green economy: a review of concepts, definitions, measurement methodologies and their interactions. *Geo: Geography and Environment* 4(1): 1-23. doi: 10.1002/geo2.36

8 Contacts

The contribution of the following people is acknowledged and greatly appreciated. They have been extremely helpful in navigating the range of materials informing this work:

David Style

Senior Analyst Adaptation

Committee on Climate Change

david.style@theccc.gsi.gov.uk

Tel: 020 7591 6098

Kristen Guida

Manager, London Climate Change Partnership

City Hall, The Queens Walk, London, SE1 2AA

kristen.guida@london.gov.uk

LCCP: climatelondon.org

Tel: +44 (0)20 7983 5781

Mob: +44(0)7590 447 273

Michael Mullan

Adaptation Team Leader OECD

Michael.MULLAN@oecd.org

David Ainslie

UK Environmental Accounts Lead, ONS

environment.accounts@ons.gsi.gov.uk

Tel: 01633 455847

Kit England

Climate Ready Clyde Manager, Sniffer

0141 229 7738 | 07791 332250

kit@sniffer.org.uk

Kate O'Loughlin

Low Carbon and Renewable Energy Economy Survey Lead, BEIS

020 7215 3582

kate.OLoughlin@beis.gov.uk

9 Company contacts

K-Matrix Data Services

Greetham House, Church Lane, Greetham, Rutland LE15 7NF

01572 813735

www.kmatrix.co

Ricardo Energy & Environment

Gemini Building, Fermi Avenue, Harwell, Oxon, OX11 0QR, United Kingdom.

01235 753007

www.ricardo.com

ENWORKS (ESTA *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Greater Manchester / Cumbria / Liverpool City Region*)

Lee House

90 Great Bridgewater Street

Manchester M1 5JW

0161 237 4181

info@enworks.com

©Published by The University of Edinburgh 2018 on behalf of ClimateXChange

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the publishers. While every effort is made to ensure that the information given here is accurate, no legal responsibility is accepted for any errors, omissions or misleading statements. The views expressed in this paper represent those of the author(s) and do not necessarily represent those of the host institutions or funders.